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THE
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BULLETIN

ENGINEERING EXPERIMENT STATION SERIES

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UNIVERSITY OF MISSOURI

ENGINEERING EXPERIMENT STATION

BULLETIN, NO. 1.

ACETYLENE FOR LIGHTING COUNTRY HOMES

BY

J. D. BOWLES.

PUBLISHED BY
THE UNIVERSITY OF MISSOURI
March, 1910.

The Engineering Experiment Station of the University of Missouri was established by order of the Board of Curators July 1st, 1909.

The object of the Station is to be of service to the people of the State of Missouri.

First: By investigating such problems in Engineering lines as appear to be of the most direct and immediate benefit and publishing these studies and information in the form of bulletins.

Second: By research of importance to the manufacturing and industrial interests of the State and to Engineers.

The staff of the Station consists at present of a Director and two research assistants together with a number of teachers who have voluntarily undertaken research under the direction of the Station.

Suggestions as to problems to be investigated, and inquiries will be welcomed.

Any resident of the State may on request obtain bulletins as issued or if particularly interested, may be placed on the regular mailing list. Address the Engineering Experiment Station, University of Missouri, Columbia, Missouri.

ACETYLENE FOR LIGHTING COUNTRY HOMES.

The farm home may be readily equipped in these days with every modern convenience. One of the most important of these conveniencies is a good lighting system. The oil lamp with its accompanying dirt, inconvenience, and danger, may be replaced, with the outlay of a few hundred dollars, by a lighting system almost equal in convenience and economy to a city lighting service.

Private Lighting Systems are divided into three classes: Acetylene, Gasolene, and Electric. This bulletin is the first of a series devoted to these systems; the others, Gasolene Lighting Systems and Small Private Electric Installations are in preparation.

Those who are interested may make their own comparison of these systems as to relative economy, convenience and practicability, when the series has been published.

This bulletin contains a brief discussion of the properties of Acetylene and of the Calcium Carbide from which it is derived when the carbide is brought into contact with water. The details of Acetylene Generation and of Acetylene Generators are studied, as well as the planning of a typical lighting arrangement in which are taken up in detail the factors governing the size and number of burners, the capacity of generator required, piping and fixtures, and the value of scientific shading and diffusing of the light where satisfactory illumination is desired. Cooking and heating by Acetylene is discussed briefly. The Design of a complete Installation is worked out in detail giving cost data. Village and Town Lighting Systems are briefly discussed. The appendix contains the results of tests made by the Station, a schedule of pipe sizes, and a table of dimensions and costs of Acetylene Generators, together with the list of Generators approved by the National Board of Fire Underwriters.

Useful information and data were obtained from the Acetylene Journal (Chicago) and Professor George Gilbert Pond's bulletin on Calcium Carbide and Acetylene published by the Pennsylvania State College.

The tests described were made with a 35 light Carbide Feed Generator furnished by the Eagle Generator Company of St. Louis.

The writer is indebted to Mr. K. A. McVey of the Experiment Station Corps for assistance in making the tests.

CALCIUM CARBIDE.

Calcium Carbide is the substance from which Acetylene gas is produced. It was first prepared on a promising commercial scale in 1892 by Thomas L. Willson, a young electrical engineer at Spray, North Carolina. Willson utilized the intense heat of the electric furnace, operating on a mixture of lime and coal tar. His search was for something of an entirely different nature and the discovery of Calcium Carbide and its remarkable property of producing Acetylene gas when in contact with water was purely by chance.

The Commercial Carbide is now prepared by incorporating a mixture of ground coke and lime in the proportion of 41.7 per cent and 58.3 per cent, respectively, and introducing the mass into an electric furnace where the intense heat causes chemical reactions to take place yielding 69.7 per cent of calcium carbide and the remaining 30.3 per cent as carbon monoxide which is burned at the mouth of the furnace.

Calcium Carbide is a dark gray substance more or less crystalline in structure and very hard and brittle. A cubic foot of crushed carbide weighs about 136 pounds. It may be heated to redness or higher without suffering any change. It is not affected by shock or concussion and may be preserved indefinitely when kept in air tight cans or drums. In open air gradual disintegration occurs due to atmospheric moisture.

Calcium Carbide is not affected by the ordinary solvents but when brought in contact with water vigorous decomposition ensues with the evolution of Acetylene gas and a residue of pure slaked lime. The gas and lime are formed in the proportions of 26 and 74 respectively by weight. A pound of chemically pure carbide would yield 5½ cubic feet of gas. The commercial carbide yields from 4¼ to 5¼ cubic feet of gas per pound. One pound of pure carbide would require .562 pounds of water for complete decomposition.

Calcium Carbide is packed in non-returnable sheet steel drums, containing 100 pounds each. The sizes of carbide regularly carried in stock are as follows:

"Lump"—3½ inches by 2 inches. Large pieces.
"Egg"—2 inches by ½ inch. Medium pieces.
"Nut"—1¼ inches by ⅜ inch. For Carbide Feed Generators.
"Quarter"—¼ inch by $\frac{1}{12}$ inch. For Carbide Feed Generators.

The carbide industry of this country is practically monopolized by the Union Carbide Sales Company of New York and Chicago. It is distributed by various depots over the country. The nearest depots for this state are at Kansas City, Mo., and East St. Louis, Ill. The current price of carbide at these depots is $3.75 per 100 pounds in less than ton lots and $70.00 per ton in ton lots.

The railroad companies accord calcium carbide third rate classification and carry it along with other freight.

ACETYLENE.

Acetylene is a colorless, tasteless gas having a characteristic pungent odor. It is one of the so-called hydrocarbons, having a composition of 92.3 per cent carbon and 7.7 per cent hydrogen. This gas is lighter than air, its comparative density being about .92. The corresponding figure for ordinary coal gas is .45.

Acetylene will not ignite of its own accord, but when set fire to in open air it burns with a white flame yielding carbon dioxide and water vapor. The high density and percentage of carbon in this gas is the source of its wonderful luminosity. When burned from a suitable burner which premixes the gas with a proper amount of air, an intensely brilliant white light results, the spectrum of which approaches very near that of sunlight itself. No smoke or odor is perceptible. This light on account of its whiteness is of great value for accurately distinguishing colors and is very desirable for domestic purposes, being when properly shaded, very easy on the eyes.

The combustion of Acetylene deprives the surrounding air of 2½ cubic feet of oxygen for every cubic foot of the gas burned, giving off in turn 2 cubic feet of carbon dioxide and 1 cubic foot of water vapor. For purposes of comparison we note that 1 cubic foot of coal gas requires 1 cubic foot of oxygen and throws off ¾ cubic foot of carbon dioxide. Now the ½ foot Acetylene burner giving 25 candle power consumes ½ cubic foot of gas per hour. The ordinary open coal gas burner giving from 18 to 25 candle power consumes 5 cubic feet of gas per hour. Thus we see that for equal illumination Acetylene impoverishes and pollutes the air only about one-fourth as much as coal gas. Now a coal oil lamp of the best kind will give about 25 candle power and consumes approximately one gallon of coal oil for twenty hours use. The oil lamp impoverishes and pollutes the surrounding air to a far greater extent than either of the above gases.

For equal candle power illumination Acetylene causes less heating of the surrounding air than coal gas and far less than the coal oil lamp.

Acetylene is considerably less poisonous than the coal gas which is ordinarily used for illumination. Fatal results from inhalation are not on record and it is said they could not possibly occur until the gas exists in the proportion of more than 20 per cent. The danger to be apprehended from this source is too remote for serious consideration. The steady escape of gas from an open half foot burner in an air-tight room 8 feet square and 8 feet high would produce a mixture of 5 per cent in 50 hours. The characteristic odor of the gas will attract attention to an open burner or a leak long before harm could result from same.

Contrary to the general concensus of opinion which seems to prevail, Acetylene is not a dangerous illuminant. However, this gas possesses in common with other illuminating gases the property of forming a violent explosive mixture with air. The ideal mixture would be one foot of gas to about 12½ feet of air. From this condition the mixture explodes with varying degrees of violence between the limits of 20 per cent of air to 4 per cent of air. Here again the odor of the gas would be liable to attract attention to the vicinity of a leak or open burner long before a dangerous mixture could exist in a room.

It is impossible to obtain explosion or even ignition of a body of pure gas by the introduction therein of a lighted match or electric spark. However, Acetylene may be exploded by the detonation of a dynamite cap or other violent explosive in a body of the pure gas.

LIQUID ACETYLENE.

At a temperature of 68 degrees Fahrenheit and about 597 pounds per square inch pressure, Acetylene may be liquified. This liquid is of a violent explosive nature and does away with all thought of storing the gas by this means.

No one has ever succeeded in getting an explosion from Acetylene at a pressure under one atmosphere. Since the ordinary pressure of the gas under service is but a few ounces at most, it is evident that there is absolutely no danger to be apprehended from this source.

DISSOLVED ACETYLENE.

When Acetylene is compressed and forced into a tank filled with some porous material saturated with the liquid "Acetone," it seems to lose the explosive properties that it ordinarily possesses when under pressure. Acetone dissolves twenty-four times its own bulk of the gas at ordinary temperature and pressure and the quantity dissolved increases directly with the pressure applied. Now as the pressure is released the gas escapes and is delivered cool and dry to the burners.

Dissolved Acetylene finds its application with yachts, motor cars, railway headlights and railway car lighting. For ordinary house lighting it is entirely out of the question; acetylene can be provided for stationary purposes by generators so much more economically that Dissolved Acetylene finds no application here.,

Acetylene is soluble in water to the extent of eleven volumes of gas to ten of water. But the solubility of gas in water is too limited to be put to any practical use. However it is of consequence for us to know about this, for the excessive use of water in a gas generating apparatus might cause considerable loss of gas.

ACETYLENE GENERATORS.

The function of an Acetylene generator is a comparatively simple one. It provides for the bringing together of the water and the carbide, washing and filtering the gas, storing it to a certain extent, and delivering it under a small pressure to the service pipe for distribution. Acetylene generators are divided into two general classes, Automatic and Non-Automatic. In the automatic machine the gas is generated as it is used, the quantity generated being automatically governed by the rate of consumption. In the non-automatic machine a definite quantity of gas is generated at a fixed rate and stored. The former type is used for all small installations such as house lighting plants. The latter type is used for large plants, such as village lighting systems. In this discussion we are interested chiefly in the automatic generator as a private lighting plant for the country home.

The most important feature to be considered in the design of an acetylene generator is that of cool generation. When the carbide and water unite to form gas, violent chemical action occurs with the liberation of large quantities of heat. If this heat be localized, dangerous temperature rise is liable to occur. The carbide in such a type of generator would not give its full quota of gas and the burners would soon clog up due to its impure quality.

When water is fed into the carbide it is evident that there will be more or less localization of heat with consequent hot generation. Hence the most rational method would be to feed carbide in small well regulated quantities into a large body of water where the heat would be quickly transferred and dissipated. The water to carbide feed type of generator designated as the "water feed" generator is rapidly disappearing from the market and the carbide to water or "carbide feed" generator is now almost universally used.

The carbide feed generators are divided into the following classes by Mr. Einstein in the Acetylene Journal for September, 1907:

The "direct feed"—Feeding the carbide by gravity into the water by opening the feed valve which is operated directly by the gas holder bell.

The "indirect feed"—The gas holder bell operates a feeding mechanism which carries the carbide forward to the feed point where it falls into the water.

The "independent feed"—The feed valve is operated by a clockwork or motor mechanism controlled by gas holder bell.

The "indirect independent feed,"—A motor or clockwork controlled by gasholder bell operating a feed mechanism which carried the carbide forward to the feed point.

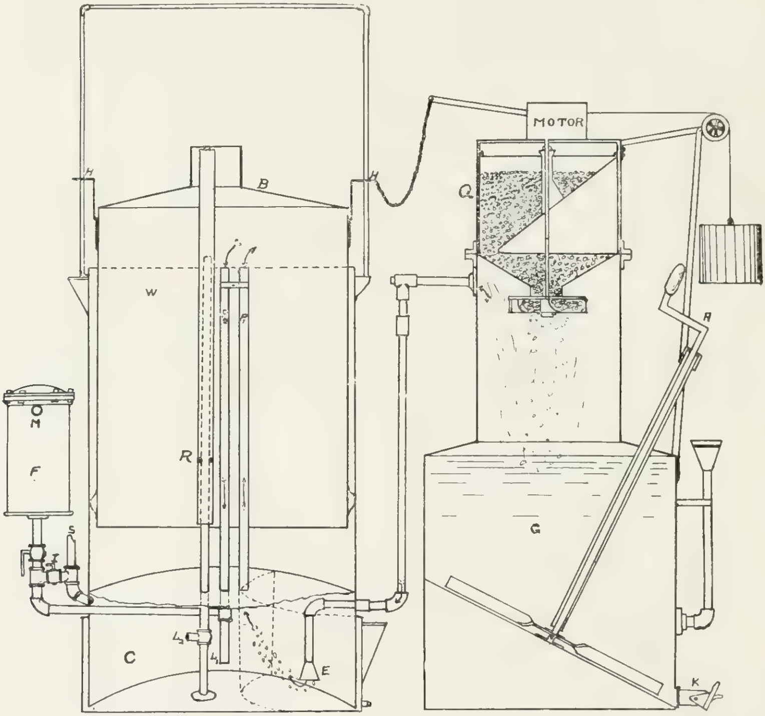
The indirect independent feed and the direct feed machines are shown in Figures 1 and 2 respectively.

The Acetylene gas machine consists of two essential parts. The generator proper and the gas holder, or gasometer as it is often called. The gasometer by the rise and fall of its gas bell regulates the quantity of gas generated and also serves as a pressure equalizer, supplying the gas to the mains at a constant uniform pressure.

A typical carbide feed machine is shown in Fig. 1. The carbide is fed from hopper Q into the body of water G. Gas is generated and passes out into the water seal E. This chamber is partially filled with water. From E the gas passes thru the pipe P_1, into the gasometer.

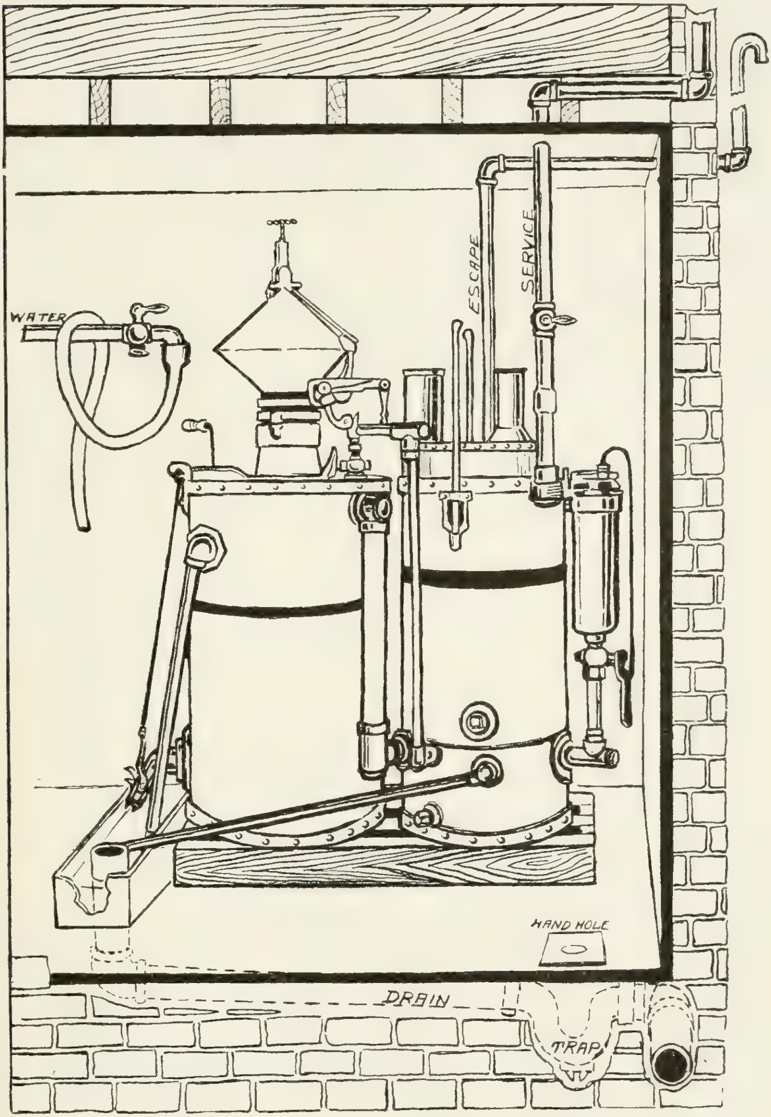
The gasometer bell is closed at the top and open at the bottom. It rests in the body of water whose surface is at W. As gas enters the bell rises, thus acting as a storage tank for the gas. The telescopic action of the bell is guided by the rods H. The gas bell supplies gas at a virtually constant pressure thru pipe P_2 and filter F to service main at M. When the bell rises to a certain height it stops the weight motor and hence carbide feed. When the bell drops below this point, carbide is again fed into the water until the bell rises above this point. The chamber C is of course filled with water to the same height as the water in E. Hence any undue pressure in gas bell will cause gas to bubble through open connection at L_1 into chamber C. If the gas bell should accidently rise too high due to a fault in the mechanism or undue after generation, the gas will enter telescopic tube at R and escape through L_2 into C. The chamber C is connected with the open air by the escape pipe S. The by-pass valve I is used should it become necessary to empty gas bell for cleaning or repairs. The generator is cleaned by agitating the contents of G with the mixer A. The mixture of slaked lime and water is then drawn off from the sludge-cock K. The handle A is water sealed as shown to prevent the escape of gas around same.

FIG. 1.



In outlining the principles of this gas machine, we have brought out the important features of all high grade Acetylene generators. They all accomplish the same results, embodying the same principles and safety

FIG. 2.



devices and differ mainly in methods of feeding carbide and mechanical details of construction.

In the water feed machine the water is slowly fed to the carbide. The carbide charge is divided in a series of separate compartments and the water gradually feeds in a free flowing stream, thus flooding the carbide. Only one cell is flooded or in operation at a time. The flow of water is governed by the rise and fall of the gas bell. This machine tho an evolution of the water feed machines of bygone days, does not embody the features of rational generation as the carbide feed machine does, and hence would be less satisfactory for ordinary purposes. However this type of generator is perfectly safe and reliable and is especially adapted to localities where water is very scare, since merely enough water is used to completely decompose the carbide, while with the carbide feed machine about one gallon of water per pound of carbide is used.

Prof. George Gilbert Pond of Pennsylvania State College says that whatever the type may be, a good generator, such as can be recommended for household use, must be possessed of certain qualities which will be conceded by all:

(1) "It must allow no possibility of the existence of an explosive mixture in any of its parts at any time. The perfect machine must be so constructed that it shall be impossible at any time under any circumstances to blow it up. It must be 'fool proof.' "

(2) "It must insure cool generation."

(3) "It must be substantially constructed of good heavy metal which is not liable to rust and cause leakage and consequent dangerous gas mixtures."

(4) "It must be simple. The more complicated the machine, the sooner it will get out of order. Understand your generator. Beware of a generator whose interior is filled with pipes, tubes, valves, and diaphragms whose functions you do not perfectly understand. If a complicated mechanism is employed to perform what seems to you a simple duty, rely upon your common sense and judgment and look further until you find a perfectly simple but strong mechanism to perform the work automatically of making the gas. There are plenty of them and you can afford to meet the price of the machine which is least likely to call for repairs next season."

(5) "It should create no considerable pressure in any of its parts. More than a pound of pressure at any point may be a source of danger; more than a few ounces is wholly unnecessary and not to be tolerated."

(6) "It should be capable of being cleaned and recharged without the loss of gas into the room. In a good machine there will be no perceptible odor in its neighborhood."

(7) "It should require little attention. All machines have to be emptied and recharged periodically; but the more this process is simplified and the more quickly this can be accomplished the better."

(8) "It should be provided with a suitable indicator to designate how low the charge is in order that filling may be done in season and the house not plunged in darkness without notice."

(9) "It should completely use up the carbide, generating the maximum amount of gas."

There are plenty of good generators on the market. No less than 52 are approved by the National Board of Fire Underwriters up to date. For years the country was flooded with many weird devices of a worthless and even dangerous character simply because this field offered so many attractive possibilities to the amateur inventor. Happily these machines have been weeded out and improved until one need select only such machines as are passed upon and approved by the National Board of Fire Underwriters. We are appending the latest approved list of Acetylene Gas Machines. This list includes many excellent and seemingly perfect machines and all on it should be safe and reliable.

PLANNING OF LIGHTING SYSTEM.

When deciding on a lighting plant for the home we might well divide our procedure into several steps. The first and most important is to accurately determine the capacity or size of machine desired. Next we select a particular make of Generator. Third, we definitely decide on a location for same. Fourth, we work out the piping scheme for the house. Fifth, we select our fixtures.

CAPACITY OF GENERATOR.

It is important to select a machine of ample size to suit all present requirements and allow a liberal estimate for future outlets. It is far better to install a machine of slightly larger than required capacity, than to find out too late that we have skimped on our original estimate. The additional first cost of a larger machine is slight and the attention required will be less, since it will have a greater carbide capacity and consequently furnish gas from one charge for a longer period of time to the same number of outlets. The National Board of Fire Underwriters advise the following rules for determining the size of generator required:

(1) "For dwellings, and places where machines are used intermittently the generator should have a rated capacity, i. e., pounds of carbide at one charge, equal to the total number of burners installed."

(2) "For stores, opera houses, theatres, day run factories, and similar service, the rated capacity should be from 30 to 50 per cent in excess of the total number of burners installed."

(3) "For saloons and all night or continued service, the rated capacity should be from 100 to 200 per cent in excess of total number of burners installed."

"This rating is based on the so-called 1½ foot burner giving a steady illumination of 25 candles and consuming 1½ cubic feet of gas per hour. (Burners usually consume from 25 to 100 per cent more than their rated consumption of gas, depending largely upon the working pressure. The so-called ½ foot burner when operated at pressures of from 2 to 2½ inches water column, is usually used with best economy.)" In addition to the ½ foot size of burner, there are the 1½ foot burner rated at 75 candle power, the 1 foot burner rated at 50 candle power, ¾ foot burner rated at 37 candle power, and the ¼ foot burner rated at 12 candle power. Two ½ foot burners with suitable shades will give plenty of light for the ordinary sized living room with light walls. A good rule to follow is to allow 2 square feet of floor area per candle power where brilliant illumination is desired. Three square feet per candle power will give good light under all conditions.

One ½ foot burner will be found ample for a bedroom unless a wall bracket is desired in addition. Be sure and allow lights for halls, porch, cellar, outhouses and barn.

If heating or cooking units are to be installed make allowances as follows:

Acetylene Range.—Each cooking burner consumes about 3 feet of gas per hour, the oven burner consumes about 5 cubic feet of gas per hour.

Hot Plates.—From 2 to 3 feet of gas per hour.

Small Bedroom Heaters.—About 2 ¾ cubic feet of gas per hour.

Now reducing everything to equivalent half foot burners and we are in a position to decide on the capacity of our proposed machine.

SELECTION OF GENERATOR.

Having a generator of definite capacity in mind, we are ready to proceed with the selection of our machine. We will in all probabilities settle on the carbide feed type since the small additional amount of water required would be an item in very few communities. If we have no stated preference for any particular make of machine, we had best write to a few representative firms given on the "Approved List" and state our case clearly and concisely. These firms will be glad to take the matter up with us, giving us detailed description of their apparatus with their cost data, advise us as to size, methods of installing and operating their particular machine, etc. Now in making our selection we should be guided by the requirements outlined by Prof. Pond and choose that machine which in our estimate conforms more nearly with these requirements.

A table of average specifications and cost worked out from leading makes of machines is appended.

LOCATION.

We must now decide on the location of our generator. It is preferably located in a special "generator house" built for this purpose, especially if the machine is of large capacity. Such a house should be provided with double walls, be well ventilated and dry, and must if necessary be artificially heated in winter to prevent danger of freezing of water in generator. It is generally more convenient and inexpensive to locate the generator in the basement of an outhouse; or it may even be located in the basement of the main building if the company insuring property consents to same in writing on its policy and it is not prohibited by certain local authorities or boards. The machine must of course be of an approved make and there must be no open jet within ten feet of the machine and it must be placed at least fifteen feet from the furnace.

The machine must be so placed that the operating mechanism will have room for free and full play and can be adjusted *without the aid of artificial light*. It must not be subject to interference by children or meddlesome persons, and it may be well to enclose the machine by a slatted partition for this reason. The generator should be placed on a strong, level, foundation. If this foundation is of wood it should consist of heavy timbers located in a dry place and open to the circulation of air as shown in Fig. 2.

PIPING.

The generator should be provided with an escape or relief pipe not less than ¾ inch internal diameter. This pipe will be installed without a trap so that any condensation will drain back to generator. It must be carried outside the building and terminate in a properly constructed hood or return bend looking down about 12 feet from the ground. The machine should discharge into a suitable open receptacle for the removal of sludge and water. This receptacle is preferably connected with a drain emptying into a sludge pit or a sewer and much labor in carrying out the lime water with pails will be saved thereby. If the premises are supplied with running water, it will be found convenient to have a tap near the generator for supplying the same with water when it is to be recharged.

If the building is already piped for gas it will only be necessary to connect service pipe in basement with the generator. If, as is usually the case, the building must be specially piped, the schedule for pipe sizes should conform to that commonly used for Acetylene gas, but in no case should the feeder pipes be smaller than ⅜ inch. A schedule of pipe sizes is appended.

The piping work should preferably be done by a regular plumber or gas-fitter. If the services of a plumber are not obtainable, the work can be done by any skillful mechanic such as may usually be found in the small towns. A good man and his helper will be able to completely pipe an average residence in three days time. If the house is an old one, it may take a little longer to make a good job of concealed work. Competent plumbers will usually agree to pipe a house complete, furnishing all material for from 10 to 15 cents per running foot.

The service connection with the generator is made with a pipe of the same size which in turn leads to a riser of the same size, running up thru the building as near the center as possible. The feeders run out from the riser at each floor and these in turn branch off to the fixtures. The feeders and branches should be of ample size as determined by the piping schedule appended.

Black iron pipe should be used with malleable galvanized fittings. Connections from generator to service pipe should be made with right and left thread nipples, or long thread nipples with lock nuts. Unions should never be used for gas fitting. All piping should be pitched to drain back into the generator. If low points occur thru necessity, they must be drained thru tees into drip cups permanently closed with screw cap plugs. Never use pet cocks. Apply a little white lead to all threads before coupling up to insure gas-tight joints. The piping must be rigidly supported by hooks and straps. Outlets for brackets or drops must be secured by straps or flanges, which are nailed or screwed to the woodwork. Always use fittings in making turns; do not bend pipe. Do not use unions, but instead use long thread, or right and left hand couplings. Long runs of approximately horizontal pipe must be firmly supported at proper intervals to prevent sagging. All longitudinal outlet-pipes must be taken from the sides or top of running lines, never from below. All ceiling outlets must project not more than 2 inches nor less than ⅝ inch, and must be firmly secured and plumb. Side wall outlets must be firmly secured and must not project more than ⅝ inch and must be at right angles to the wall. Where pipes pass thru masonry walls they must be incased. Pipes must be run and covered so as to be readily accessible. Do not run at bottom of floor beams which are to be lathed and plastered. They must be securely attached to the top of the beams which should be notched as shallow as possible. Where pipes are paralleled to beams, they must be supported by strips nailed between the two beams, about four feet apart. Floor boards over pipes should be fastened down by screws, so that they can be readily removed.

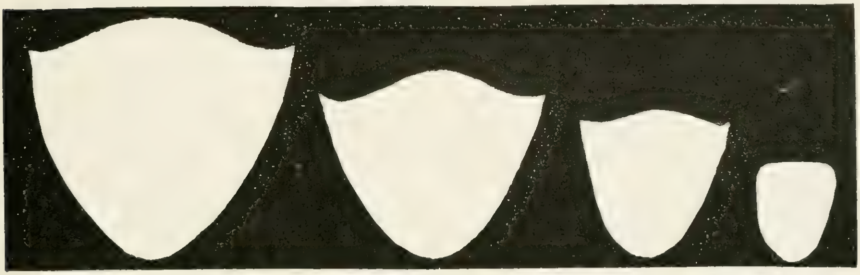
FIXTURES.

In the matter of fixtures one is guided entirely by his own taste and by the amount of money he is willing to appropriate for the purpose. Fixtures may be procured in a variety of styles with from 1 to 4 lights each. The firm selling the generator will furnish a catalog of acetylene gas fixtures or refer to dealers who handle them.

Inexpensive fixtures may be made by building them up from common ½″ or ⅜″ black iron pipe and painting or gilding to suit. Such fixtures are commonly used for store lighting.

The fixtures may be fitted with any of the standard burners already referred to. The actual size of flame produced by these burners is shown in Fig. 3. The appearance and actual size of the ordinary acetylene burner is shown in Fig. 4.

FIG. 3.



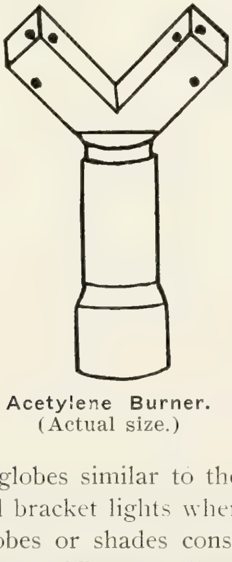
1 cu. ft.	¾ cu. ft.	½ cu. ft.	¼ cu. ft.
50 C. P.	37 C. P.	25 C. P.	12 C. P.

Actual Size and Appearance of Acetylene Flames.

For residence lighting the fixtures should hang about 6 1-3 feet from the floor. For bedrooms they may be hung slightly lower however, and wall brackets should be placed about 5 ½ feet from the floor.

When ordering fixtures be sure and measure the ceiling heights and state the length of each fixture in the order.

FIG. 4.



Acetylene Burner.
(Actual size.)

It is advisable to use globes similar to the Holophane Glass Globes for use with all fixture and bracket lights where good illumination is desired. These are glass globes or shades constructed along well known optical principles so that they diffuse the light by cutting down the intense glare, with practically no loss by absorbtion. At the same time they increase the useful light below the horizontal. Where reading is to be done it is imperative to have good shades since without these there will be very poor illumination directly below the light. The acetylene flame due to its high intrinsic brillancy will dazzle the eye when looked at directly. The light will also cast very sharp shadows due to its small size. All of this will be remedied by the proper use of diffusing globes or shades.

These globes are made in three classes. "Class A"—adapted for use over dining room and library tables, desks, counters, etc., where a strong light is wanted directly downward. "Class B"—for general illumination such as for lighting parlors, bed rooms, stores, etc. "Class C"—designed to give maximum light just below the horizontal, and therefore adapted for use in low chandeliers, wall brackets, etc., where it is desired to light a large area. Especially recommended for illuminating long hallways as corridors, large rooms, etc.

ACCESSORIES.

Electric Ignition. With a special style of automatic burner and an electric ignition outfit, one can have light by the simple pressure of a button on the wall. The battery and coil are concealed in any convenient nearby closet or in the basement. Such an outfit costs in the neighborhood of twelve dollars. It is very convenient and safe for barns where an enclosed light must be used and matches are dangerous. The same sort of an appliance with a chain pull igniter instead of the push button variety may be had for about six dollars. One battery and coil may be used in connection with any number of burners.

HEATERS AND COOKERS.

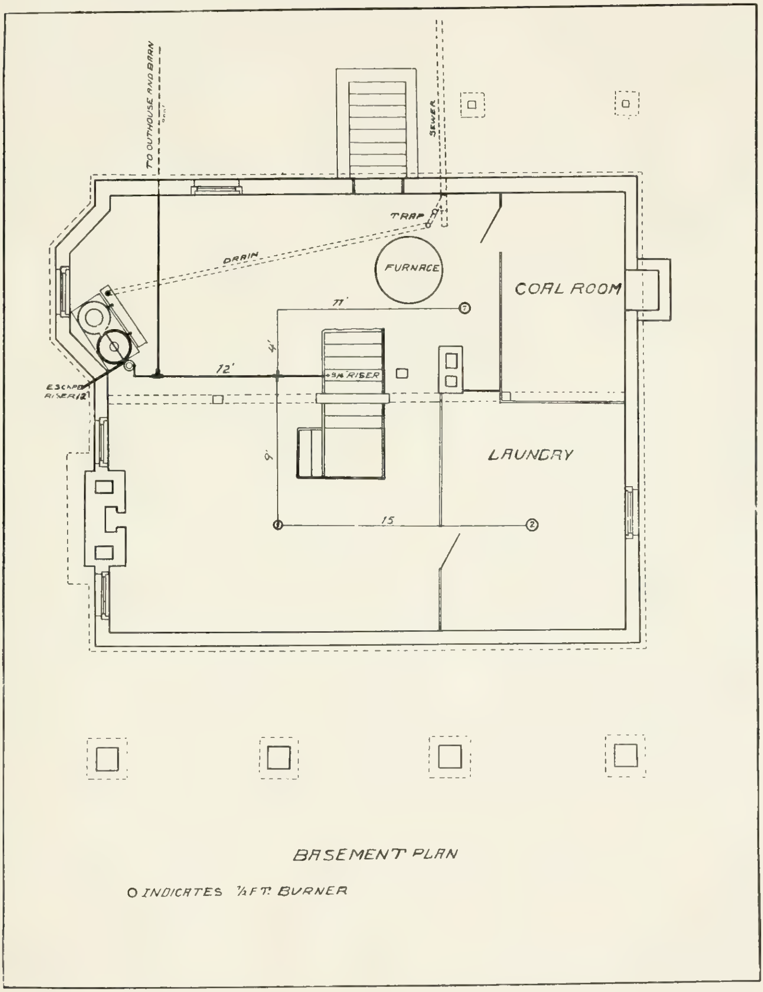
The heating value of Acetylene is about two and one-half times that for ordinary coal gas. With carbide at its present price this does not make the cost of heating and cooking by acetylene at all prohibitive. This would certainly be a useful and convenient adjunct to lighting by acetylene, as cookers and heaters of numerous sizes and varieties designed especially for use with Acetylene gas are now on the market. Acetylene Ranges of the four burner style with a large oven may be purchased at a surprisingly low figure. The consumption of gas per burner is three feet per hour. The oven consumes about five feet per hour, and it is said will bake biscuits in ten minutes. A variety of cookers and hot plates are available. Chafing dish heaters may be had consuming 1 ½ feet of gas per hour. Bath and bed room heaters are also available.

The portable heaters may be connected with a nearby jet with a rubber tubing. If a gas range or cooker is installed, a permanent connection should be made with the generator by a separate lead.

DESIGN OF A TYPICAL INSTALLATION.

We will now go into the details of a typical installation for a country home whose plans are shown in Figures 5, 6, and 7. On the first floor are Dining and Living Rooms, Parlor, Reception Hall, Pantry, and large front porch. On the second floor are three Bedrooms, a Store Room, Hall and Bath Room. In the basement there is a Furnace Room, Fuel Room, Laundry and Store Room.

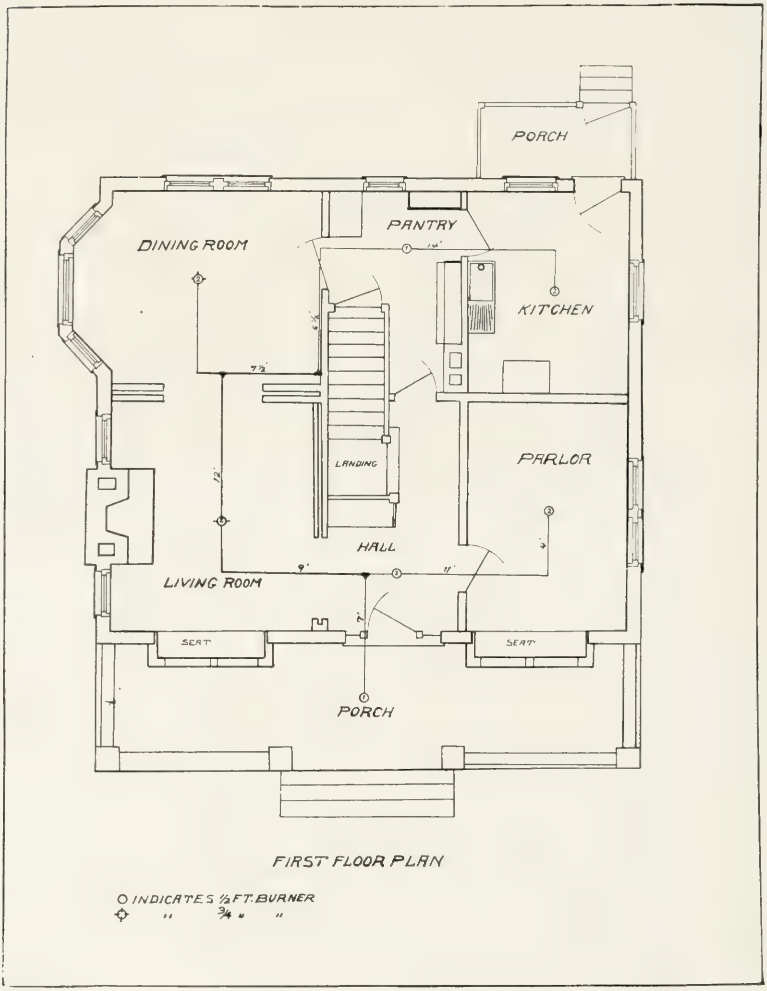
FIG. 5.



LIGHTING ARRANGEMENT.

Living Room.—This room should be well lighted, since more time is spent here by the family than in any other room in the house. The light should be well distributed below the horizontals to admit of several persons reading in the room at the same time. Accordingly we select a two-light fixture with ¾-ft. burners and Holophane Shades, Class B. This will give a very brilliant lighting below the horizontal and also good general illumination over walls and ceiling.*

FIG. 6.



Dining Room.—Brilliant illumination is desired over the table. We will select a two-light fixture hung in the center of the room with ¾-ft. burners and Class A Holophane Globes.

Kitchen.—Here the housewife spends a great part of her time. The operations carried on here are of vital interest and importance to the entire family. It should be well lighted though not so brilliantly as the dining room. A simple two-light fixture with ½ ft. burners and Class B Holophane Globes will suffice here.

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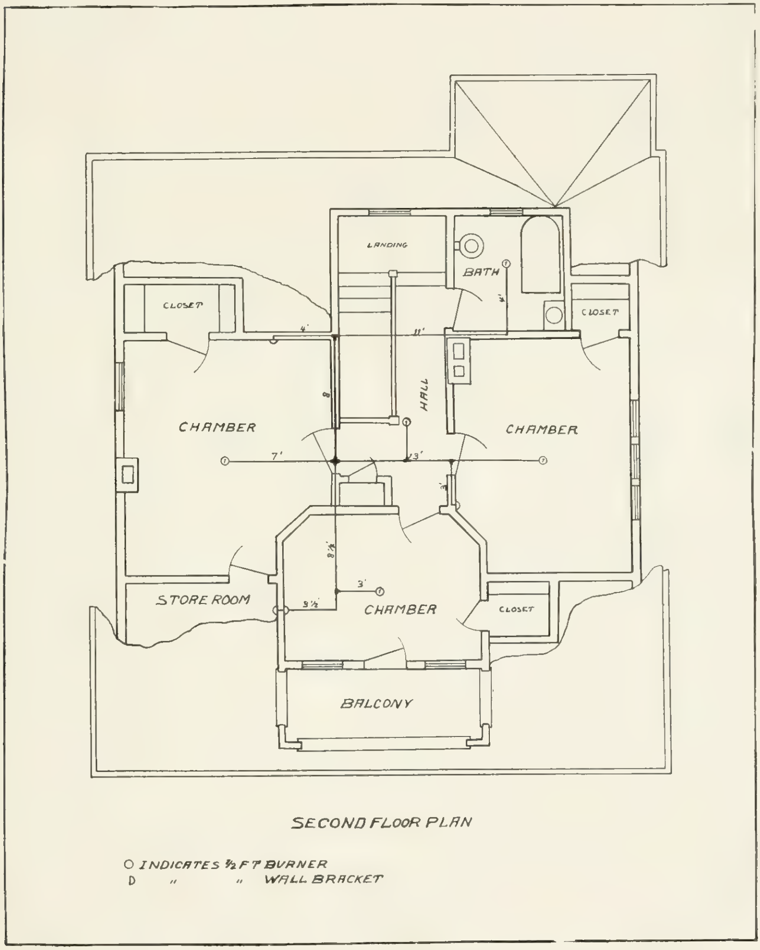
*All fixtures will be placed 6 ft. 4 in. off the floor unless otherwise specified.

Parlor.—A two-light fixture with ½ ft. burners will be ample for this room. We may use Holophane Globes of Class B type, or select globes of a more elaborate or tasteful design to harmonize with the general scheme of decorations in the room.

FIG. 7.



Pantry and Bath Room.—One-light fixtures with ½ ft. burners and Class B Shades.

Halls.—One-light fixtures with ½ ft. burners and Class C shades should be used for the halls.

Front Porch.—A regular porch light fixture with a ½ ft. burner and suitable globe and canopy to protect it from wind will be used here.

Bedrooms.—These chambers are each fitted with one-light ceiling fixtures with ½ ft. burners and Class B globes. These ceiling fixtures are hung about 6 ft. off the floor. "Two swing" brackets with ½ ft. burners and Class C globes are placed on wall in each room so as to give a good light near mirror to dress by. These brackets should be placed about 5 ½ feet off the floor.

Basement.—An open ½ ft. burner is placed near the furnace. One is also placed in the store room. A short two-light bronze spread equipped with ½ ft. burners is placed in the laundry. It will be noticed that light is placed in the vicinity of the generator.

Outhouse and Barn.—The outhouse is equipped with two ½ ft. wall bracket burners. The area way of the barn is lighted by an enclosed ¾ ft. burner equipped with an electric chain pull igniter.

CAPACITY OF GENERATOR.

Adding up all of our outlets we find that we have twenty-two ½-ft. and five ¾ ft. burners. The equivalent is about thirty ½ ft. burners. We will select a "size 50" or 50 light generator, since this will allow for any under-rating of the burners and also allow liberally for future extension.

INSTALLATION AND PIPING.

We will assume that the company insuring the property consents to our placing the generator in the basement. We will thus be saved the added expense of an outhouse which would have to be specially heated in the winter. The machine will be placed about 20 feet from the furnace near the basement window. A nearby window is desirable so that all cleaning and charging may be done without the aid of artificial light. A wooden foundation is made for the generator as shown in Fig. 2. A trough of heavy galvanized iron about 8″ x 8″ x 26″ is placed in front of the machine and connected with a 2″ drain which in turn leads to the sewer thru a suitable trap. This trough and drain will merely be an added convenience and may be dispensed with if it is proposed to use the sludge for some practical purpose when it is emptied from the machine. However, if drain is to be used never connect directly with a sewer, but let generator first discharge into a suitable open receptacle which may in turn have such connection.

A 1 inch escape pipe is led outside and terminates in a weather bend about 12 feet from the ground. A ¾ inch service pipe connects with generator thru a long thread nipple with lock nuts. The service pipe is led to a ¾ inch riser which reaches the ceiling of the second floor. Half inch feeder pipes are led off from the riser at each floor as shown. These feeders in turn branch off into ⅜ inch pipes which lead to the outlets. The reductions of ½ inch to ⅜ inch are clearly indicated on the plans which show piping arrangement, Fig. 5-6-7.

A ¾ inch galvanized pipe is laid underground to supply two ½ ft. burners in an outhouse and a ¾ foot burner in the barn. The total length of this outside piping system is 200 feet.

ESTIMATED FIRST COST OF INSTALLATION.

Piping System.

18 feet of 1 inch pipe, 235 feet of ¾ inch pipe, 40 feet of ½ inch pipe, 177 feet of ⅜ inch pipe	$ 22 00
Pipe Fittings	5 00
Labor, 1 man at $3.50 per da. for 4 days	14 00
Labor, 1 man at $1.50 per da. for 4 days	6 00
Total Cost of Piping	$ 47 00

Drain.

Galvanized iron trough	$ 2 00
20 feet of 2 inch pipe	2 60
Fittings, trap, etc.	3 00
Labor	2 00
Total Cost for Drain	$ 9 60

Foundation for Generator.

Wood open work Foundation	$ 1 00

Fixtures.

Dining Room, Living Room, Parlor: Two-light, polished brass finish, turned brass fittings	$ 16 50
Pantry: One light bronze	1 00
Kitchen: Two light bronze	2 00
Hall: One light polished brass	3 50
Porch: One light crystal globe, canopy windguard	5 50
Bed-rooms: Three, one light polished brass	6 00
Bed-rooms: Three, Brackets, 2 swing, polished brass	4 50
Bath-room: One light, polished brass	2 00
Hall Upstairs: One light, polished brass	2 00
Basement: Two one light bronze	2 00
Laundry: Two one light bronze	2 00
Outhouse: Two bronze brackets	1 40
Barn: Enclosed globe with chain pull igniter and accessories	13 00
Total	$ 61 40
Discount at 20 per cent	12 28
Actual Cost	49 12

2 Dozen Holophane Globes	16 00
2 Dozen 2 ¼ inch Holders	3 00
Total	19 00
Discount at 33 1-3 per cent	6 32
Actual Cost	12 68
2 ½ Dozen Acetylene Burners	6 00
50 Light Generator	158 00
Cost of Installation Complete	$283 40

Allowance for Freight and incidentals will bring this figure to $290.00.

TOTAL ANNUAL COST.

The actual cost of Acetylene at the rate of ½ foot of gas per hour with carbide giving 4 ½ feet of gas per pound and costing $4.00 per 100 pounds, would be ½ cent per hour. This would be the cost of operation for a burner consuming ½ foot of gas per hour. However, the total annual cost based on such a figure as this would be of little value since no allowance has been made for fixed charges. To estimate these we assume a 5 per cent interest rate, and a 4 per cent rate of depreciation on the generator, (the life of the generator is rather uncertain since it depends materially on its location and the attention it receives, such as thoroughly cleaning and painting it about once a year), and 2 per cent on the piping and fixtures. We will allow 1 ½ per cent for taxes and repairs. Now in order to know the amount of carbide which would be used per year, we will have to approximate the gas consumption of our lighting arrangement. The gas used per day will of course vary with the season, being considerably higher during the winter days than during the summer. A careful study of the number of hours each burner is likely to be used will give an average gas consumption of 12 cubic feet per day for the year round. Assuming our carbide as giving an average yield of 4 ½ cubic feet of gas per pound, we would use annually 975 pounds. The generator would need recharging on the average every 18 days. Now our total yearly cost will be:

Carbide: 975 pounds at $4.00 per 100 pounds	$ 39 00
Interest on $290.00 at 5 per cent	14 50
Depreciation on generator at 4 per cent	6 32
Depreciation on piping and fixtures at 2 per cent	2 64
Taxes and repairs at 1 ½ per cent	4 35
Total Yearly Cost	$ 66 81

This is about $2.20 per equivalent half foot burner installed.

A CHEAPER INSTALLATION.

In making the above estimates liberal allowances have been made and the design is perhaps more elaborate than desired for the average country home.

We may reduce the cost of the above installation materially as follows: Omit the drain in cellar and arrange to carry out the sludge in buckets or pump it out with a small pump and hose attachment which is made for that purpose. Omit light in barn and on the porch. Bronze instead of polished brass fixtures in bed rooms. Using a 35 light generator instead of the 50 light machine will reduce the cost by $23.00 alone. The total first cost of this installation would now be in the neighborhood of $225.00.

By turning out lights when not needed the carbide consumption for such an installation may be reduced to 650 pounds per annum.

The total annual cost will now be:

Interest on $225.00 at 5 per cent	$ 11 25
Depreciation, Repairs, Taxes	10 50
Carbide: 650 Pounds at $4.00 per 100 pounds	26 00
Total Yearly Cost	$ 47 75

These figures it will be understood are merely estimates made to cover the average case and will vary for different localities and with the extent of the installation. However, they will serve as a guide to those interested in applying them to their individual proposed installations.

CARE OF APPARATUS.

Rules and requirements of the National Board of Fire Underwriters for the construction, installation and use of Acetylene Gas machines and for the storage of Calcium Carbide, may be obtained from your insurance agent or by writing to Secretary's office, National Board of Fire Underwriters, No. 207 East Ohio Street, Chicago, Ill.

Complete directions for operation and care of apparatus will accompany the generator. However, we deem it advisable to point out some of the more important points to be considered in general where using any Acetylene Gas Machine.

Always recharge generator before carbide is entirely consumed, and observe a regular time during daylight hours only for attending to and recharging the apparatus. The sludge should be emptied from generator and it should be thoroughly flushed, then filled with clean pure water *each* time the carbide hopper is recharged.

The semi-liquid residue drawn from the generator may be used for white washing, as a fertilizer, insecticide, and disinfectant. The lime will make mortar which will set quickly and hard.

It is often convenient and inexpensive to let the drain from generator empty into a sludge pit where the lime will accumulate and can subsequently be used.

The water in the gas holder should be drained off once or twice a year and the holder thoroughly cleaned. The felt in the filter will need occasional renewing. This is easily observed by the dimming of lights when all are all turned on, due to the pressure of gas falling below normal in passing the felt. Always keep the tanks and seals filled with clean water.

When starting up a new installation open all burners till gas has forced the air out of the pipes before attempting to light burners.

Never test the generator or piping for leaks with a flame and never apply a flame to an outlet from which the burner has been removed.

Never use a lighted match, lamp, candle or lantern near the machine.

Never pack or ram the carbide in the hopper and use only such size of carbide as the directions call for.

If the generator is installed in a separate generator house, this house should be thoroughly ventilated and any artificial heating necessary to prevent freezing shall be done by steam or hot water systems.

STORAGE OF CALCIUM CARBIDE.

Calcium Carbide in quantities not to exceed 600 pounds may be stored when contained in drums not exceeding 100 pounds each, inside insured property, provided the place of storage is dry, weatherproof and well ventilated and also provided that all but one of the packages shall be sealed until the unsealed can has been completely used up.

In excess of 600 pounds, packages must be stored above ground in detached buildings used exclusively for this purpose, being dry, well ventilated and weatherproof.

VILLAGE PLANTS.

Lighting by Acetylene is not necessarily limited to residences or single buildings. Plants are being annually installed of sufficient size to illuminate towns of from 400 to 3,000 inhabitants. This furnishes a cheap, effective, and very satisfactory method of lighting small towns where coal gas plants would be failures and electric plants doubtful propositions.

The operating expense of a village plant is very low, since the services of but one man are required about one or two hours per day in attending and recharging the generator. The rest of the time the generator house is locked up and the generator takes care of itself.

Such a plant as we have already mentioned, is equipped with a non-automatic generator and a gas holder of sufficient capacity to contain at least four cubic feet of gas per ½ foot burner of the rating.

The carbide is fed into the water by hand or by a small water motor so that a slow and steady feed is assured. It is customary to generate enough gas at one time to last at least over a single night and often for several nights. Ample storage is desired so as to avoid the possibility of the gas supply ever failing and being turned on again while the burners are still open.

The station apparatus consists of a generator which is equipped with a cast iron filter, seal pot and suitable feeding device. Also, a station meter which is of sufficient capacity to measure all gas supplied from gas holder to the mains, a heating apparatus installed in a separate room and of sufficient size to keep the generator room at 50 degrees Fahrenheit in zero weather and a residuum drain of 6 inch vitrified terra cotta pipe connecting discharge gate of generator with an outside pit. The water supply is furnished by a standard pressure water system for supplying all water necessary for operation of plant, including the driving of the water motor such as is used for operating the feeding device. This water supply may be furnished by an elevated tank supplied by a pump and gasoline engine or windmill.

The gas holder is constructed in accordance with specifications furnished by the firm selling the generator. All mains and supply pipes are also installed in accordance with these specifications.

The price on a complete station equipment made to us by a prominent manufacturer of a non-automatic central station generator was $2500.00. The plant has a capacity of 1,000 cubic feet of gas per hour, and the gas holder has a capacity of 1500 cubic feet. A larger generator having a capacity of 2500 cubic feet of gas per hour and a gas holder of 3,000 cubic feet capacity, would cost about $3300.00. These prices include hot water heating plant installed, station meter, etc. The smaller size would be ample for a town of 1500 inhabitants or less. The larger size for 3000 inhabitants or less.

The cost of installing, mains, etc., will of course depend entirely on local conditions. However, the first cost of a municipal Acetylene lighting plant for a small town will be less than any other kind of lighting system. The cost of operation will certainly be much lower.

Small towns which have heretofore been in darkness simply due to the fact that a gas or electric plant could not be made to pay, may be beautifully and economically lighted by Acetylene.

We have in mind a small town in the State of Minnesota of about 500 inhabitants. They have a municipal Acetylene lighting plant which has been giving satisfactory service for eleven years. The gas is metered to the consumers at a rate of $1.25 per 100 cubic feet. The village allows a flat rate of $2.00 per month each for the town street lamps. This plant has a capacity of 1000 cubic feet of gas at a charge and requires the attention of one man a half hour each day. The first cost of this plant was $3500.00 as installed eleven years ago.

A pressure equivalent to a 4 ½ inch water column is maintained on the gas in the mains. This rather high pressure is necessary to force the gas in sufficient quantities to the ends of those service pipes which extend considerable distance from the plant.

The Union Carbide Company makes a rate of $60.00 per ton to municipal plants.

APPENDIX

RESULTS OF TESTS.

We conducted a series of tests in our laboratory in order to observe the actual consumption of gas for various rated burners and also to determine the cubic feet of gas available per pound of carbide under service conditions.

The generator used for the test was a 35 light carbide feed machine which was loaned to us by the Eagle Generator Company of St. Louis, Missouri.

The arrangement of generator, meters and burners for the test is shown in Fig. 8.

A Junker's Wet Meter was used for measuring the gas consumption of the burners per hour. A Maryland 3 light meter was also connected in the service line and carefully callibrated to measure the total quantity of gas used from a charge of carbide.

A pressure equivalent to a 2½ inch water column was maintained on the gas with an average temperature of 70 degrees Fahrenheit thruout the test on the burners.

We found that the ½ foot burners were but very slightly underated but that the larger sizes of Eagle burners seemed to be somewhat overrated. The results were as follows:

Eagle Burners.

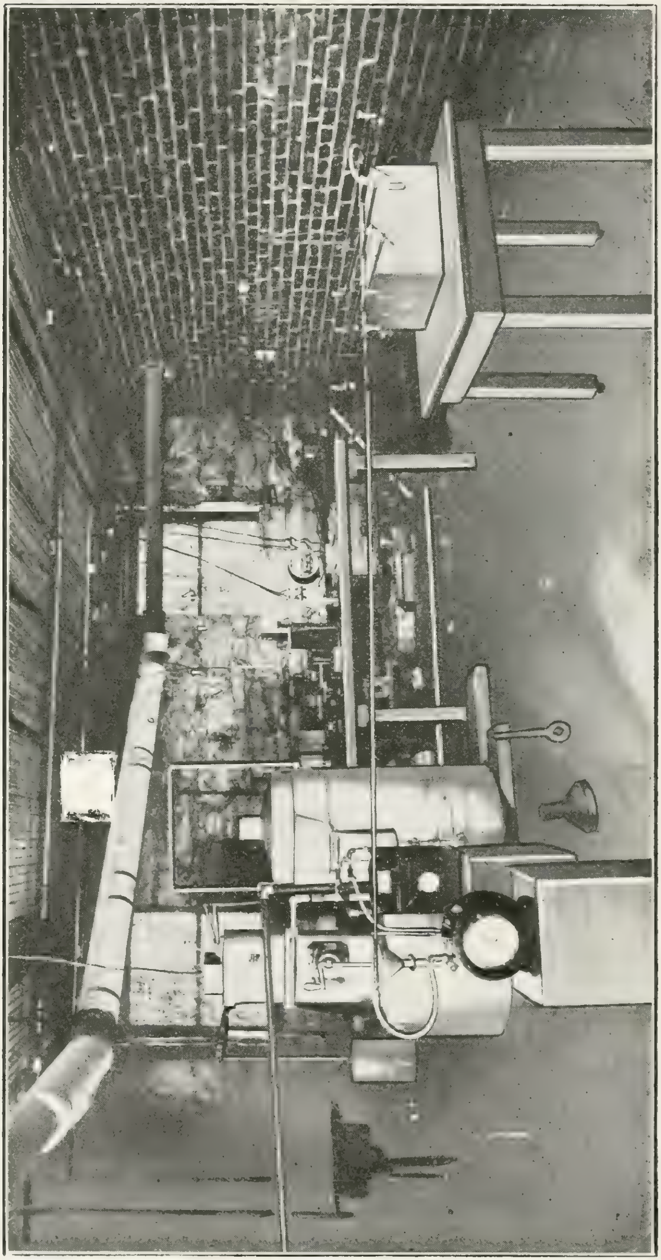
Rating of Burner in cubic feet per hour.	Actual consumption cubic feet per hour.
1½	1.04
1	.785
¾	.584
½	.537
¼	.360

Colts Von Schwarz Perfection Burners:

Rating of Burner in cubic feet per hour.	Actual consumption cubic feet per hour.
1	1.01
¾	.811
½	.524
¼	.35

These figures were averaged from four runs on two burners of each size.

FIG. 8.



35 Light Carbide Feed Generator Arranged for Test.

Carbide from two different drums was tested. The contents of the first drum was very dusty and a strong odor of Acetylene prevailed when the drum was opened, indicating a slightly air-slaked condition. The average gas yield from carbide of this drum was 4.1 cubic feet per pound. Carbide tested from the second drum yielded 4.67 cubic feet of gas per pound. These are the actual figures which would be obtained under service conditions, as the usual procedure of expelling air from the generator was gone thru when starting up, and the gas was burned from a bank of burners several hours each day until the charge was exhausted.

APPROXIMATE DIMENSIONS AND COST OF AUTOMATIC ACETYLENE GENERATORS.

Rating—No. ½ Foot Lights.	Carbide Capacity—Pounds.	Height Required—Inches.	Floor Space Required—Inches	Width of Door Required—Inches.	Service Pipe—Inches.	Weight—Gross—Pounds.	Price—Dollars.
20	20						100
25	25	75	24x40	22	½	250	120
30	30						135
35	35	80	27x58	25	¾-1	425	150
40	40						160
50	50	86	28x60	26	¾-1	500	175
75	75						250
100	100	92	34x68	30	1-1 ½	600	300
150	150						400
200	200	116	48x75	38	1 ½-2	1200	550
300	300						750
500	500	120	75x130	48	2	2500	1050
1000	1000						1650

Note:—The above are list prices and are usually subject to 10 per cent. or more discount.

PIPING SCHEDULE FOR ACETYLENE GAS.

No. ½ ft. Burners.	DISTANCE IN FEET AND SIZE OF PIPE REQUIRED.													
	10	20	30	40	50	60	75	100	125	150	200	300	400	500
10	3/8	3/8	3/8	3/8	3/8	3/8	3/8	1/2	1/2	1/2	1/2	3/4	3/4	3/4
20	3/8	3/8	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4
30	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1/4	1
40	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/8	3/4	1	1	1
50	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/4	3/4	1	1	1	1	1
60	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/4	1	1	1	1	1	1
75	1/2	3/4	3/4	3/4	3/4	1	1	1	1	1	1	1	1 1/4	1 1/4
100	3/4	3/4	3/4	3/4	1	1	1	1	1	1	1	1 1/4	1 1/4	1 1/4
150	3/4	3/4	1	1	1	1	1	1	1	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2
200	3/4	1	1	1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2	2
250	1	1	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	2	2	2
300	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2	2	2	2
400	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/4	1 1/2	1 1/2	1 1/2	2	2	2	2	2 1/2
500	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2	2	2	2	2	2	2	2	2 1/2	2 1/2

LIST OF ACETYLENE GAS MACHINES

which have been examined under the Rules and Requirements of

THE NATIONAL BOARD OF FIRE UNDERWRITERS

By Its Committee of Consulting Engineers

and which may be permitted for the uses specified when installed according to requirements
if not in violation of any state law or local ordinance, and

IF THE COMPANY INSURING THE PROPERTY CONSENTS TO THE SAME IN WRITING ON ITS POLICY.

To secure the largest measure of safety to life and property, Acetylene Gas Machines must be installed outside of buildings, and the National Board Rules strictly observed.

It should be noted that the installation of acetylene gas machines inside of buildings is prohibited in certain districts by local authorities and local boards.

The following named Acetylene Generators made by the persons and firms whose names are given have been examined and tested under the direction of this Committee, the factory practices used by these concerns are inspected from time to time and the manufacturers are under agreement to furnish for sale under these names only devices which are similar in all respects to samples and specifications on file at the Underwriters' Laboratories.

They are safeguarded to as great an extent as it is possible to safeguard appliances of this character.

Be sure that the trade name, and the name of the manufacturer, as given in the list, are marked on the machine, and that the generator purchased is of the type manufactured since the date of the examination

Follow carefully the Rules for Proper Installation, Care and Maintenance of Acetylene Generators, a copy of which may be obtained from your insurance agent.

CLASS A.

STATIONARY APPARATUS FOR ISOLATED INSTALLATIONS.

Acetylene Report No.	Name of Machine	Manufactured by	Manufactured at	Date of Original Exam.	Date of Last Re-exam.
198	Abner Giant	The Krein Mfg. Co.	Wapakoneta, Ohio	July 1909	June 1908
260	Abner, Jr.	The Krein Mfg. Co.	Wapakoneta, Ohio	March 1901	Feb. 1909
372	A Free Light	Martin Bros.	Maryville, Mo.	April 1905	Sept. 1908
261	Aurora	Hercules Mfg. Co.	Chattanooga, Tenn.	July 1901	May 1908
473	Beloit	Acetylene Gas Machine Co.	Beloit, Ohio	June 1909	....
343	Ben Hur	The Johnson Acetylene Co.	Crawfordsville, Ind.	Jan. 1902	April 1908
482	Birch	Birch Acetylene Co., Chicago, Ill.	Elkhart, Ind.	Sept. 1909	....
438	Brauer	Brauer Acetylene Lighting Co.	Marshalltown, Iowa	Jan. 1907	Aug. 1909
40	Buckeye	National Light and Heating Co.	Freeport, Ohio	April 1898	May 1908
419	Bunnell	Robinson & Love	Sycamore, Ill.	March 1906	Sept. 1909
373	Carter	Niagara Falls Acetylene Gas Machine Co.	Niagara Falls, N. Y.	Jan. 1903	July 1909
216	C. K. Sober	C. K. Sober	Lewisburg, Pa.	Nov. 1899	Feb. 1909
346	Colt, Model N.	J. B. Colt Co.	New York, N. Y.	April 1902	Sept. 1909
420	Colt, Model O.	J. B. Colt Co.	New York, N. Y.	Nov. 1905	Sept. 1909
434	Comet	Comet Acetylene Apparatus Co.	Alexandria, Minn.	Aug. 1906	Aug. 1907
211	Condon's	U. S. Acetylene Co.	Philadephia, Pa.	June 1907	Feb. 1909
337	Davis, Model B.	Davis Acetylene Co.	Elkhart, Ind.	Dec. 1901	March 1909
383	Davis, Model C.	Davis Acetylene Co.	Elkhart, Ind.	April 1903	March 1909
36	Daylight	Daylight Acetylene Gas Co.	Louisville, Ky.	March 1898	Aug. 1909
450	Daytonia	St. Clair Mfg. Co.	Dayton, Ohio	Sept. 1907	Oct. 1909
1	Eagle	Eagle Generator Co., St. Louis, Mo.	Chicago, Ill.	June 1897	March 1908
265	Gate City	Visser & Brown	Keokuk, Iowa	April 1901	Aug. 1909
391	General	Commercial Acetylene Co.	New York, N. Y.	Sept. 1903	April 1909
369	Grand Rapids	G. F. Owen	Grand Rapids, Mich.	Jan. 1903	Feb. 1909
418	Hays	J. T. Hays & Son	Emmitsburg, Md.	Jan. 1907	Feb. 1909
448	Hercules	Hercules Mfg. Co.	Chattanooga, Tenn.	Jan. 1907	May 1908
365	Higgs	Davis Acetylene Co., for Home Carbide Co., Chicago, Ill.	Elkhart, Ind.	Jan. 1903	March 1909
440	Holm	Springfield Acetylene Generator Co.	Springfield, Ohio.	Dec. 1906	Feb. 1909
482	Hunter	Hunter's Gas Co., Chicago, Ill.	Elkhart, Ind.	Sept. 1909	....
240	Ideal Epworth, Type D.	Ideal Epworth Acetylene Co.	Waterloo, Iowa	Sept. 1900	Sept. 1900
246	Ideal Epworth, Type D.	Ideal Epworth Acetylene Co.	Johnstown, Pa.	March 1907	Oct. 1909
403	Illinois	Monmouth Acetylene Electric Mfg. Co.	Monmouth, Ill.	Nov. 1905	March 1909
338	King	C. A. King	Norwich, N. Y.	Oct. 1902	Jan. 1908
71	Laum	Laum Bros.	Chicago, Ill.	Aug. 1898	Feb. 1908
464	Model	National Welding & Mfg. Co.	Buffalo, N. Y.	May 1908	Sept. 1909
253	Monarch Carbide Feed	Monarch Acetylene Gas Co.	Buffalo N. Y.	July 1904	Sept. 1909
410	Night Commander	United States Standard Co.	Voorheesville, N. Y.	Aug. 1905	Nov. 1907
282	Orion	Matteson Acetylene Gas Generator Co., successors to Boonville Acetylene Generator Co., Boonville, N. Y.	Pulaski, N. Y.	Oct. 1904	Jan. 1908
340	Phelps Carbide Feed	The New England Mfg. Co., Chicago, Ill.	Elkhart, Ind.	April 1903	Aug. 1909
468	Phelps Limited Feed	The New England Mfg. Co., Chicago, Ill.	Elkhart, Ind.	Sept. 1909	....

CLASS A—Continued.

Acetylene Report No.	Name of Machine	Manufactured by	Manufactured at	Exam. Original Date of		Date of Last Re-exam.	
454	Phelps Measured Feed	The New England Mfg. Co., Chicago, Ill.	Elkhart, Ind.	July	1907	March	1909
404	Pilot, Model B.	The Acetylene Apparatus Manufacturing Co.	Chicago, Ill.	Oct.	1904	Jan.	1909
386	Pilot, Model C.	The Acetylene Apparatus Manufacturing Co.	Chicago, Ill.	Feb.	1903	Jan.	1909
428	Pilot, Model D.	The Acetylene Apparatus Manufacturing Co.	Chicago, Ill.	May	1905	Jan.	1909
381	Radiant	The Rush Acetylene Generator Co.	Canandaigua, N. Y.	Feb.	1903	Dec.	1908
388	Reliance	The Gem City Acetylene Generator Co.	Dayton, Ohio	Dec.	1904	March	1909
482	Stiles	The New England Mfg. Co., Chicago, Ill., for W. E. & A. Stiles, West Chazy, N. Y.	Elkhart, Ind.	Sept.	1909	....	
482	Strimple	The New England Mfg. Co., Chicago, Ill., for Strimple's Acetylene Co., Peoria, Ill.	Elkhart, Ind.	Sept.	1909	....	
354	Sunlight Omega	Sunlight Gas Machine Co.	New York, N. Y.	July	1902	Sept.	1909
347	Victoria, Model B.	Victoria Mfg. Co.	Auburn, Me.	Feb.	1902	Sept.	1909
385	Western	Western Gas Company, Chicago Ill.	Reddick, Ill.	Sept.	1908	....	
430	Aceterator	General Light Co.	Philadelphia, Pa.	Sept.	1906	Feb.	1909
	This generator is considered suitable for use only when installed in a masonry pit, with the generating water below the frostline, located outside of and at least 30 feet removed from buildings.						

CLASS B.

STATIONARY APPARATUS FOR CENTRAL STATION SERVICE.

Acetylene Report No.	Name of Machine	Manufactured by	Manufactured at	Date of Original Exam.		Date of Last Re-exam.	
239	Williamson	Acetylene Apparatus Mfg. Co.	Chicago, Ill.	April	1902	Jan.	1909

CLASS D.

PORTABLE TABLE LAMPS.

Acetylene Report No.	Name of Lamp.	Manufactured by	Manufactured at	Date of Original Exam.	Date of Last Re-exam.
429	Beck Iden	Acetylene Lamp Co.	New York, N. Y.	Sept. 1905	June 1908

CAUTIONS.

1.—Calcium carbide should be kept in water-tight metal cans, by itself, outside of any insured building under lock and key, and where it is not exposed to the weather.

2.—A regular time should be set for attending to and charging the apparatus during daylight hours only.

3. In charging the generator chambers of water-feed machines, clean all residuum carefully from the containers and remove it at once from the building. Separate from the mass any unslaked carbide remaining, and return it to the container, adding new carbide as required. Be careful never to fill the container over the specified mark, as it is important to allow for the swelling of the carbide when it comes in contact with water. The proper action and economy of the machine are dependent on the arrangement and amount of carbide placed in the generator. Carefully guard against the escape of gas.

4. Whenever recharging with carbide always replenish the water supply.

5. Never deposit residuum or exhausted material from water-feed machines in sewer pipes or near inflammable material.

6. Water tanks and water seals must always be kept filled with clean water.

7. Never install more than the equivalent of the number of half-foot burners for which the machine is rated.

8. **Never test the generator or piping for leaks with a flame, and never apply flame to an outlet from which the burner has been removed.**

9. **Never use a lighted match, lamp, candle, lantern or any open light near the machine.**

10. See that the entire installation is in accordance with the rules of the National Board of Fire Underwriters, a copy of which will be furnished by your insurance agent, and obtain from your contractor a written guarantee that these rules are complied with.

Note. Failure to observe the above cautions is as liable to endanger life as property.

University of Missouri

Engineering Experiment Station

Bulletin No. 2 June, 1910

WATER SUPPLY FOR COUNTRY HOMES.

By Karl A. McVey.

An improvement is noticeable at the present time in the sanitary surroundings of farmers' homes. This improvement is the natural outgrowth of the increased requirements for comfort and refinement in the home. The healthful pleasure of life in the country, either at the country residences or on the farm, so often marred by the absence of comforts which in city life come as a matter of course, is being brought about by what is known as "modern conveniences." The introduction of these improvements depends largely on having or providing an abundant supply of pure water. It is a great step toward insuring the health of the household dependent upon the water, and increasing the wholesomeness and healthfulness of the milk, butter, cream, and other products used on, and sold from, the farm.

The idea is general that water supply and house sanitation are extremely expensive. This, however, is far from being the case, and in the installation of a water system, if it be kept within the bounds of utility, avoiding that which is luxurious, the cost is considerably less than might be anticipated.

It is the purpose of this bulletin to outline some methods of water supply, draw attention to the importance of the sanitary aspect of the supply and to give an idea of the cost of making such improvements.

The methods of supply described are not new but have all been tried for some time, nor are any claims to originality made. It is believed, however, that the different methods are not generally known and an exposition would be of value. The costs, which have been given, of course can only be taken as approximations, but at this time and place are reasonably close to those which would prevail in the rural districts of the state. The question of water supply naturally leads to a consideration of sanitation and sewage disposal, which phase of the question will be taken up in a following bulletin.

SPRINGS.

Springs are the natural outlets at which underground water flows out at the surface. In some parts of the country springs yielding pure water are numerous and are a cheap and valuable source of supply. As a rule their waters are palatable, wholesome, and free from organic impurities owing to the natural filtration going on while it passes through the subterranean strata before it reaches the surface. It is best and most convenient if springs are found located at an elevation considerably higher than the house and grounds to be supplied, for then the water may flow by gravity and the necessity of some form of pumping machinery is done away with.

In contemplating a water supply obtained by tapping a spring, it is of importance to give attention to the variation in the yield of the spring, which occurs almost regularly at the different seasons of the year. It is much safer in all cases to defer the gauging of the spring until after dry weather has set in, and to select a spring only in case it yields, even at such times of drought, an excess of water over the maximum supply required.

To protect the spring against contamination it is necessary to wall it in, or still better, to construct a small storage basin in which the night flow can be stored, thus providing a reserve. This should have a reasonably tight cover to exclude surface impurities, dust, and animals. A cheap method of obtaining this storage would be to direct the flow from spring into a sunken barrel and from this have the supply pipe leading to the house. This pipe should enter the side of reservoir about six inches from the bottom, thus permitting a settling of suspended matter to the bottom from which it can be periodically removed. A strainer should be placed on the outlet pipe, inside the barrel or other reservoir provided, to prevent any foreign matter entering, which the covering has failed to exclude.

In the popular mind springs are supposed to represent the purest of supplies, but under certain circumstances this type of ground-water may not be wholly pure. Often in rough and rocky districts the depth and thoroughness of percolation over and through rock masses is so limited that the water may not equal in purity the normal ground-water. Generally, spring waters before exposure to surface of soil are deficient in micro-organisms, as they represent filtered waters, but as they appear at the surface, the water comes again in contact with organic matter and soil bacteria, and they receive a considerable number of organisms from this course.

.Thus can be readily seen the importance of walling in a spring where it issues from the ground and making the surface drainage good in the vicinity of the spring, forestalling the possibility of contamination by surface waters from cultivated, manured fields.

WELLS.

Wells are used in the country probably more than any other source of supply. Water from them is really rain water which has percolated through the soil down to a water bearing stratum; it is in some cases purified by its percolation through the soil, in others it is changed in character and made "hard" by reason of having dissolved and taken up mineral constituents from the geological strata through which it flows. While springs are natural outlets, wells may be considered artificial ones, for they have to be sunk, dug, driven, or drilled to the water bearing stratum, and furthermore, the water must be lifted by pumping to be of use, except in the case of true artesian wells which occur rarely in this state.

It is usual to distinguish between shallow and deep wells, yet there is no sharp demarcation between the two; the designations "shallow" and "deep" really refer more to the nature of the underground strata which the well pierces. Wells to a depth of from 15 to 30 feet, to water flowing in a superficial layer of gravel or sand which rests upon an impervious stratum are considered shallow wells. These wells should be looked upon with suspicion because they are liable to become polluted, particularly in densely settled regions, but not to a lesser degree on the farm, if they be located close to outhouses, cesspools, stables, or in close proximity to cultivated, manured fields.

These wells are either dug and lined with brick or stone, or "driven," that is, a pipe bearing a pointed perforated shoe is driven into the ground to a depth of the underground supply. These driven pipes are often only wrought iron tubes from one to three inches in diameter, and it may be mentioned here that the diameter of wells has not so great an influence on the yield as is commonly supposed. Very large supplies may be obtained from wells only 4, 6, or 8 inches in diameter.

In most cases the driven is superior to the dug well, because there is not the same amount of danger of pollution by surface leakage.

Deep wells sunk in gravelly or sandy soil, are driven or bored with tools similar to an auger or else a casing is forced through the earth into which the well pipe is inserted after the proper depth has been reached. In other cases, prevailing in most instances, when wells are sunk through rocky strata, chisel drills are used which are alternately raised and lowered, at the same time being rotated. Wells of this type are often wrongly designated artesian wells, as this term can with propriety be applied only to those wells in which water flows out at the surface.

Contamination of Wells: In locating a shallow dug or driven well, it is of importance that the sanitary aspect of surroundings be taken into consideration. It is generally believed that wells located above, that is, on a higher level than privy vaults and cesspools, are free from pollution by these sources. This, however, is not always true for "above" and "below" refer, not to the surface slope, but to the direction the water flows underground, and to the relative level of the porous or water bearing strata. When a large quantity of water is pumped from a well the underground conditions of flow may be altered. The water in the well would not alone be lowered, but also the surface of the underground water sheet for a distance all around the well. This distance increases with the amount of pumping, and while cesspools might under ordinary conditions be without the zone of contamination, pumping much water from the well will bring them into this zone. The fact whether a connection between well and cesspool exists may be established by several tests; one of the simplest being the salt-test, in which a large quantity of salt is thrown into the cesspool, then testing the water in the well by a chlorine test. Another is in the use of fluorescent "uranine," which gives to the well water a bright aniline green color.

The importance of protecting the farm well from surface pollution can not be over estimated. To bear out this statement we cite the results of the work of the Geological Survey of the United States Government in examining the farm water supplies in the State of Minnesota. Of 79 supplies examined, 20 were good and 59 polluted. In an examination of 28 dug wells, 15 had poor surface drainage and for other reasons 20 out of the 28 have a poor sanitary aspect. The drilled and cased wells show up much more favorably. It is safe to assume that the same results would be shown by an examination in the rural districts of Missouri. The remedy in most cases is easy; and lies in providing a tight impervious covering to shed all surface water and by giving the upper end of the well a water-tight lining to a depth of several feet. This can be done to the old well, or the new one under construction, by having the upper courses laid in a good cement mortar, and the surface, preferably the outside, covered with a coating of cement about three-fourths inch thick to a depth of 4 or 5 feet. The surface of ground surrounding the well should be given a gradual slope in all directions from the well curb.

The purification of a water supply is not of much interest to the dweller of a country house, for in most cases a pure supply is readily obtainable. However, there is one item under this subject well worth considering and that is, the growth of algæ which is likely to occur in pure waters. Algæ is a species of subaqueous fungus growth which usually appears as a green scum. While this is not considered detrimental to health, it gives to the water a peculiar, fishy flavor which makes it unpleasant for drinking. There is a cheap and very efficient remedy for the treatment of this condition, which consists in making a dilute solution of copper-sulphate (blue-vitriol) in the water affected. The usual method of doing this is to immerse in the affected spring, pond or tank, a coarse bag containing an amount of copper-sulphate sufficient to make a strength of about one in four millions—something like one and one-half grains in weight of the sulphate to each 100 gallons of water. The growth of this fungus may be so prolific as to stop up the pipes from the tank or springs.

CISTERNS.

In localities where underground water is hard to obtain and unfit for use, cisterns are a very common form for farm water supplies. They are used for the storage of water from various sources but usually for rain water. They may be constructed of brick and mortar, concrete, stone under-ground, or of galvanized iron placed in any convenient place. If well located and protected the latter should be satisfactory. It is the common practice to place these iron tanks above ground and during the summer season the temperature is higher than that of the water in the underground types, and the growth of organisms, which are usually present in waters collected from roofs is encouraged rather than discouraged. A roof which catches the water for a cistern also collects anything carried in the air. The character of the materials deposited there will, of course, depend upon the locality and season of the year. Some of the most common are dust, dead insects, excreta of birds, and spores of plants. The water from new roofs is in nearly all cases unfit for use, and will have to be discarded for the first few rains.

The opportunities for pollution, after the water enters the cistern depend chiefly upon the construction and protection of the types of cistern in use. Leaks offer one of the greatest opportunities for pollution if the cistern be located beneath the surface, for sometimes ground water has free entrance. Ground water around cisterns is very frequently polluted, for in its passage through the surface soil, very little if any, purification is effected. It is better if cistern be so constructed that no surface water is allowed to filter into it. The quality of the cistern water can be much improved by installing a device for turning away the water caught during the first part of a shower. There are many automatic devices for accomplishing this, but few are in common use. A simple two-way valve at the bottom of the down spout to be turned by hand is a common and efficient contrivance if properly used.

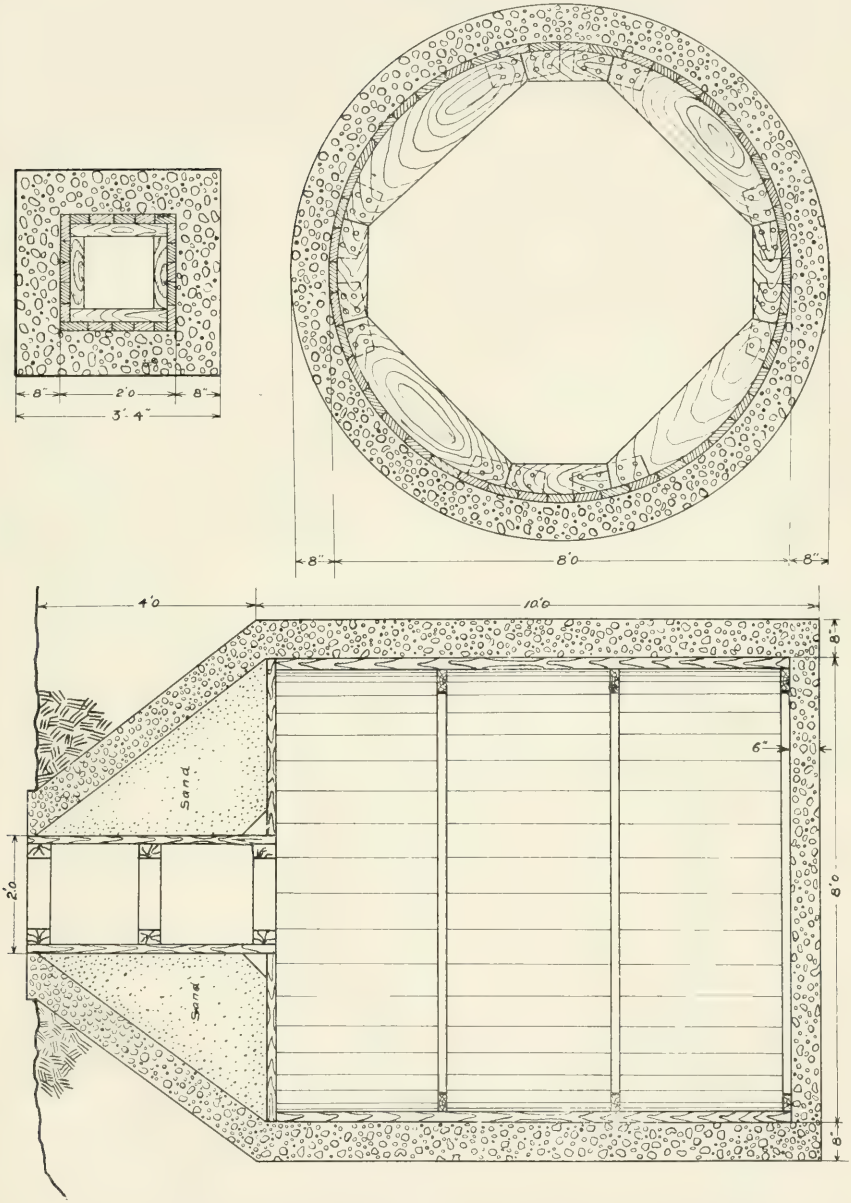
While the absence of lime salts renders it desirable for cooking, and its softeness recommends its use in the laundry, rain water on the whole is not to be considered as suitable as a pure ground water for domestic supply.

From a sanitary viewpoint, the safest and most durable underground cistern is probably that made of concrete. The designs for two of this type, together with the probable cost will be gone into.

Concrete Cistern: Make a circular excavation 16 inches wider than the desired diameter of the cistern and say 14 feet deep. Make a cylindrical inner form the outside diameter of which will be the diameter of the cistern. This form for a 14 foot hole should be about 10 feet long. Saw this form into sections for convenience in handling. Lower these sections into the cistern and then unite them to form a near perfect circle, blocking them up 6 inches from the bottom. (See figure 1.)

Make a concrete of Portland cement one part, clean sand 2½ parts, and gravel or broken stone 5 parts—which is known as a 1:2½:5 mixture. Mix in small batches just soft enough to pour. Fill in space between form and earth with concrete, and ram or puddle with a narrow scantling to keep from forming rock pockets. To construct the conical portion, build a floor across the top of the cylindrical form, leaving a hole in the center two feet square. Brace this floor well with uprights from the bottom of the cistern. Around the edges of the hole, and resting on the floor described, construct a vertical form extending a little above the surrounding ground. Build a cone shaped mold of earth or sand wetted good from the outer edge of flooring to the top of form around square hole and smooth well with a trowel or float. Place a layer of concrete 4 or 5 inches thick over the cone of sand and smooth to outer edge of side wall. After setting for a week one of the floor boards can be removed and the cone form of sand will fall gradually to bottom of cistern from where it can be easily removed together with the rest of the lumber used for forms. The bottom should be laid of same material as walls about six inches thick. If the water comes to the cistern from the house roof, and a kitchen pump is used, these pipes should be placed through the forms before concrete is put in so that they may be rigidly held in place. The materials for two different sized cisterns and their approximate cost is shown in table 1.

Fig. 1.



CONCRETE CISTERN SHOWING ARRANGEMENT OF FORMS.

TABLE I.

Cisterns—MATERIAL AND COST.

14′ deep (10′ cyl. 4′ cone) 8′ diameter, Capacity 3 800 gals.

	Parts.	*Amount.*	*Cost.*
Cement	1	43 bags	$17.20
Sand	2½	4½ cu. yds.	6.75
Gravel	5	9 cu. yds.	27.00

Lumber for forms, 225 bd. feet.

13½′ deep (10′ cyl. 3½′ cone) 6′ diam. Capacity 2 100 gals.

	Parts.	*Amount.*	*Cost.*
Cement	1	31 bags	$12.40
Sand	2½	3 cu. yds.	4.50
Gravel	5	6½ cu. yds.	19.50

Lumber for forms, 200 bd. feet.

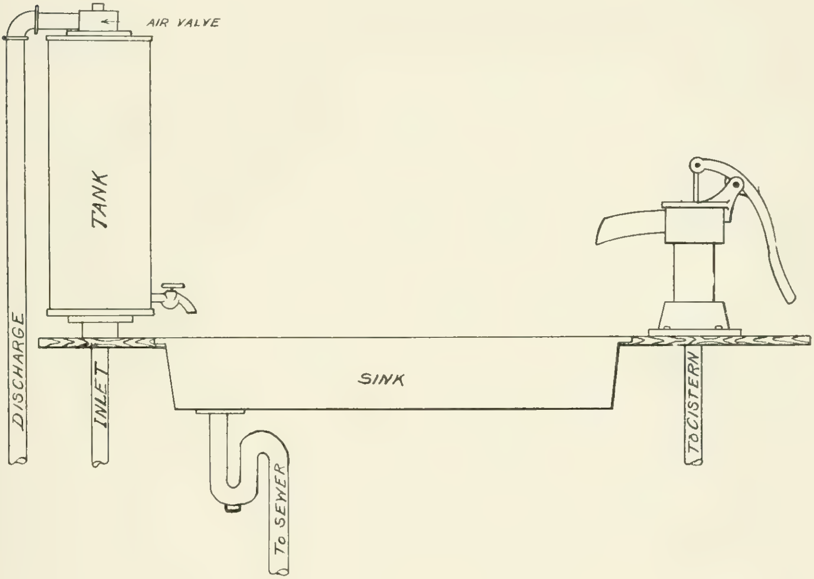
The cost of a cistern can be made close to the cost of materials provided the sand and gravel, and the lumber for forms are easily obtained. The labor item will probably equal that of any type of cistern but scraps of lumber can be used in the forms, or new can be bought and when through with can be used for other purposes. If there is a neighboring creek, sand and gravel can be had from it, but care must be exercised in collecting or it must be washed clean before making into concrete. Thus it will be possible that only the cement will have to be purchased on the market.

A farmer in central Missouri built a concrete cistern 16 feet deep by 10 feet in diameter at a cost of $70, exclusive of the labor of his helper. As his system is ingenious and can be duplicated on many farms throughout the state, we will outline it here.

Advantage is taken of a hill which rises higher than any of the barn yards. On this was erected the concrete cistern, half above the ground and half below. This is filled by a 6 foot windmill erected over a nearby dugout spring, which runs almost continuously. From this cistern pipes are laid and water flows by gravity to three concrete watering troughs situated at convenient points in the barn yard. The water level in each trough is controlled by an automatic float valve. As the cistern is large, storage enough is provided to tide them over the days during which there is insufficient wind to work the mill.

Use of Kitchen Pump: A small force, or pitcher spout pump placed at one end of the kitchen sink, with the suction pipe reaching to the cistern, is a convenient means of getting the soft water supply if the more expensive method of using a gravity tank or a pneumatic tank and piping the soft water to wash basins and bath tub are not desired. Figure 2 shows in outline such an arrangement supplemented by what is known as an automatic house tank. This tank is placed at end of kitchen sink and water from windmill pump runs through it and then to stock tanks or barns. An air-valve at top of tank lets out any trapped air and tank fills with water. This allows the freshest and coolest water in house for drinking. The capacity of the tank should be 25 or 30 gallons to provide a reserve if the mill should stop pumping. A relief valve is placed in line pipe in well and is so arranged as to open at a certain pressure. It has no connection with working of the tank except in cases of extreme pressure, when it opens to relieve tank and insures against bursting should the pipes become clogged or frozen. An estimate of the cost of such an installation as shown in figure 2 is a follows:

Fig. 2.



Cistern pump, 3 inch cylinder	$ 8.00
Kitchen sink, 18 x 30 inches	6.00
Tank complete, with air and relief valve	11.00
Pipe, say 25 ft. 1¼ inch galv.	5.50
Pipe, say 30 ft. 1 inch galv.	4.80
Installing above	4.00
Total	$ 39.30

The last three items, of course, can only be roughly estimated, as the locations of cistern and well will determine the length of pipes needed.

ELEVATED TANKS.

House Tanks: The water required at the farm buildings may be stored in inside tanks, which may be located in the attic or in the barn. These tanks are of wood, lined with copper, or of wrought iron or steel. The wood tanks while usually constructed square or oblong for use in the attic of the house, can be made in most any shape and be adapted to utilize any available space under the roof of the house. The objection to inside tanks is that their size must necessarily be limited, not only to the want of space but also because of the heavy weight of water which can not always be safely carried. This is more readily appreciated when reduced to figures. Say a tank holding 200 gallons is placed in the attic; this means a weight of 1666 pounds, exclusive of the tank which weighs about 125 pounds; which means that provision has to be made in the construction of the house to sustain this safely and this in the majority of cases can not be done without considerable expense. This objection is not so much the issue if the tank be placed in the barn where the necessary supports can be conveniently erected.

Another objection to placing the tank indoors is the socalled "sweating" which occurs when the tank is filled with cold water. It is especially bad in the case of bare iron tanks. This phenomenon is due to the condensation of the moisture in the air, on the outside of the tank. When the difference in temperature between water in the tank and the surrounding air is great, this condensation may be collected in such quantities as to run down the sides of the tank, endangering the plastering of the rooms below. This may be of little consequence in barns. This difficulty is overcome by using metal-lined wood tanks, or providing a covering of some kind—the frost-proofing would serve this purpose.

Outdoor Tanks. For the majority of farm buildings water can be raised into, and stored in outdoor elevated tanks. These may be made of wood or sheet steel and the supporting structure be of wood, steel, or masonry. Combinations often occur such as a wooden tank on steel tower, or an iron tank on a wooden tower. If left open and bare, elevated tanks often mar the landscape, so in nearly all cases they are covered and ornamented in some way. Since protection has to be afforded from frost, this wood covering can be nicely finished and painted, when it will add, rather than detract anything from the scenic value. Tank towers should be proportioned and constructed so as to be amply strong to carry their heavy load. They must be on firm foundations carried below the frost line to resist the heavy wind pressures to which they are subjected. The height of tower is determined by the pressure under which the water is to be delivered.

Wooden tanks of any appreciable size are always built round, because the circular shape is the best to secure tightness. Cypress lumber is used largely in the southwestern states, while in the East white pine is preferred. The strength of wooden tanks depends chiefly on the hoops which are either flat or round. The round hoops are the best because they can be easily examined, and protected from rust by frequent painting. It is essential in the erecting of a wood tank to support all its weight on the bottom. This is done by laying sleepers short distances apart across the entire base, and sawing them off a few inches inside the tank circumference.

The reasons why wooden tanks are preferred to steel tanks is that the latter are more difficult to erect, they give trouble by sweating, and have to be painted frequently to keep from rusting. It is also harder to protect a steel tank from freezing. Where large capacities are necessary, of course steel tanks are used, but for country estates the wooden ones are preferred. In practice it is found they will last from 15 to 20 years, and they can be bought and put up for much less money than can the steel tanks.

PNEUMATIC SYSTEM.

In addition to the attic and tower tanks which are now so generally used to supply country houses, there is another system, known as the pneumatic water supply, which has many advantages over the older methods. This system is of comparative recent origin and depends in its operation upon compressed air. The use of this system is dependent only on one condition, and that is, the ability to secure a good supply of water from well, cistern, or spring, from which it can be pumped. The most important advantage of this system is the fact that the tank may be located anywhere; either in the cellar, stable, underground, or at any other place where there is no danger of freezing.

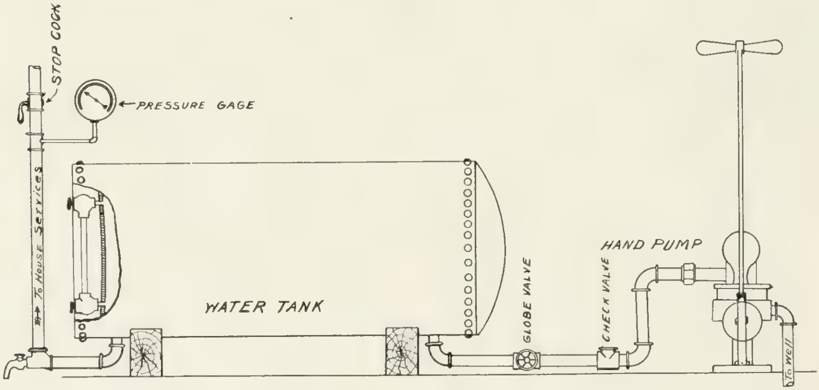
This allows the water in the piping to be maintained under pressure without using an elevated tank with its attendant evils, such as danger of leakage, straining of timbers under its great weight, etc. The tank is of wrought iron or steel, air-tight, and can be filled by windmill, power pump driven by gasoline engine, or by hand. Either a horizontal or vertical tank may be used, as suits the convenience.

Principle of Action. Water is pumped into the bottom of this air-tight tank, and as the water rises the air above it is compressed. The expansion of this compressed air will force the water through the supply pipes at the bottom of the tank to points where the water is required. The pressure in tank is increased by pumping water into it and decreased by drawing it off. The correct amount of air can be supplied and maintained by an automatic air valve, by a pump that forces both air and water into tank at the same time, or by a hand air valve. This is necessary to prevent tank being completely filled with water, a condition called "water-logged," which will prevent any pressure being gotten up.

If the tank is supplied by a windmill, an automatic pump should be used which will throw the wheel out of gear when a certain pressure is reached, and when water is drawn, the reduction of pressure will throw it in gear again. An installation of this kind has been in use on a Cooper county farm for the past four years. The windmill, an 8 foot mill on a 25 foot galvanized steel tower, and automatic pump erected cost $100. The pneumatic tank, capacity 6 barrels, was put in by a local firm for $60. The owner advises that the operation has been excellent, requiring practically no attention and since tank is underground, has experienced no inconvenience during freezing weather.

In Figure 3 is shown a complete outfit for the average sized country home. The tank is 30 inches in diameter by 8 feet in length, having a total capacity of 295 gallons and will deliver about 200 gallons without refilling.

Fig. 3.



As the space taken is small, it can be located in the basement. The water is pumped with a small hydro-pneumatic hand pump which is satisfactory provided the lift is not over 20 feet. On this pump a hand air valve is provided, so that by opening this and pumping the correct amounts of air and water can be maintained.

The approximate cost of an outfit of this kind ready to connect to service pipes in house is about $64, being proportioned as follows:

Pneumatic tank, 30 in. x 8 ft., cap. 295 gal.	$ 42.00
Hand pump, 3 in. cyl. 1¼ in. suction	10.00
Gage and water glass fittings on tank	5.00
Pipe fittings (shown in figure)	7.00
Total	$ 64.00

The advantages of a pneumatic system are many. It not only does away with the attic tank but allows the apparatus to be located conveniently to the pump, where the operation can be watched; the danger of freezing, common to elevated tanks placed outdoors is avoided, also the expense of erecting towers to support such tanks. The advantage to be gained by placing the tank underground, is that water delivered by it has nearly a constant temperature through the year. The application of this system covers a wide range, for it may be used on the farm to supply not only the house, but also the stables, wash room, dairy, lawns, and gardens.

If demand is not too great, one large tank may be used, otherwise the pressure will have to be pumped up oftener. It is good practice to have pumping time come but twice a week by having a tank large enough to hold supply for three days.

HOT WATER SUPPLY.

A hot water supply may be furnished by an independent heater and boiler in the basement, by connection to a coil in the furnace, or as is usual in country houses which have neither basement nor furnace, by a boiler and water back attached to the range in kitchen.

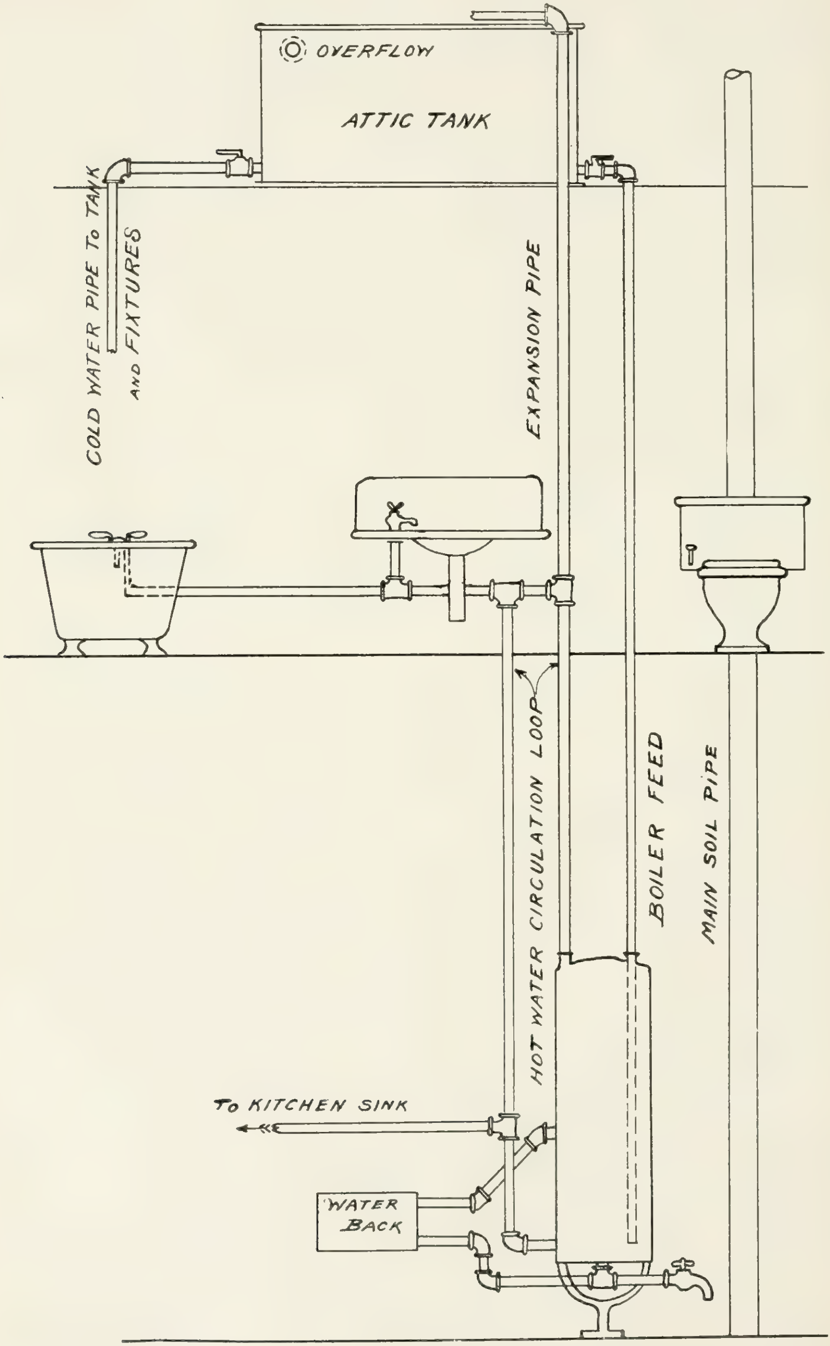
Whenever the house supply is from an attic tank, the hot water supply must be under tank pressure, in the use of which system an expansion pipe is necessary. In figure 4 is shown the arrangement of pipes for a successful water heating and circulating system.

The cold water should always enter the boiler at some distance below the entrance point for hot water from the range water back. The kitchen boiler is simply a storage tank to keep a supply on hand so that it can be drawn when needed. Certain hard waters will rust out a galvanized boiler in a few years while a copper boiler will last indefinitely, but its cost is prohibitive, and in nearly all cases these kitchen boilers are galvanized iron of 30 to 40 gallons capacity. As difference in price is small, it is preferable to install the larger tank.

The upper pipe connecting the water back and boiler should not sag but have a continuous rise from range to boiler, entering boiler as high as is practicable, and be of reasonably large size, in order that circulation will be good and water in boiler will heat rapidly. To prevent pounding and the consequent noise in the boiler, the expansion pipe is provided to allow steam and air a ready escape. Any sediment accumulating in boiler can be drawn off at the faucet at base of boiler, which in all cases should be provided.

Since when using an attic tank the available water is limited, it is desirable to draw hot water from faucets at the instant of opening, without having to wait until a long pipe is emptied with the consequent waste of water. The use of circulating pipes, if properly

Fig. 4.



ARRANGEMENT OF HOT WATER PIPING.

installed obviates this disadvantage. As shown in the figure, the hot water pipe is started from the top of the boiler, where the hottest water is, carried up to highest fixture, then down to base of boiler. Since it is preferable to use the least pipe, bath room should be located directly above the kitchen, as it not only simplifies piping but secures a much safer plumbing installation.

For simplicity, only the hot water piping is shown in the figure. A reputable plumber furnishes the writer with the cost of this installation as follows:

Attic tank, capacity 150 gals.	$ 6.50
Kitchen boiler, capacity 40 gals.	10.00
Kitchen force pump	8.00
Boiler connection to range	3.50
Piping, approximate	35.00

He estimates the total cost of installing the water and sewer connections to fixtures as shown, at $130.

If the house has a basement, the heating arrangement can be supplemented by a small water heater in basement to be used when hot water is needed and it is not convenient to have a fire in the kitchen range.

AVAILABLE POWER.

In each case the situation will determine what will be the most economical and convenient means of forcing water into the storage tank. The source of supply, the amount required, the available fuel and labor cost will all have a bearing on the matter. The hydraulic ram and the windmill have the advantage of operating without fuel, but fall must be available to use the ram, while with the windmill the daily supply is not always under control. Gasoline and kerosene engines require fuel and attention, but the supply is easily regulated to suit varying demands.

Windmills: A good and simple way of securing a supply of water is by the use of a windmill. Where the machine is properly constructed it will pump large quantities of water without cost practically, for the wind is free and the cost of repairs is very small. To be most efficient and to take advantage of the wind from any direction the tower should lift the wheel about ten feet above the tallest obstruction. The galvanized steel towers have proved durable and are fast taking the place of wood towers.

A combination tower carrying both wheel and tank is being made by many of the manufacturing companies under the name of "suburban outfit." Like all outside tanks, these have to be guarded against frost and the pipes leading to them have to be protected. Pipes are protected by enclosing in two or more wood casings with air spaces between. Combination pumping and power mills are also on the market at an additional cost, that will pump water, grind feed, shell corn, saw wood, etc.; but the heavier work must be done when there is a strong breeze. For pumping water in the central part of this state, where the average hourly wind velocity is about 9 miles per hour, 8-foot wheels on 35-foot towers are the most common in use. A division of the cost of one of these mills would be about as follows:

Thirty-five-foot galv. steel tower	$ 25.00
Eight-foot mill wheel	34.00
Pump, 2½" cyl., 3 way valve	14.00
Cost of erection	12.00
Total	$ 85.00

The following suggestions on windmill pumping may be of value. One of the most desirable features in this work is the efficiency of the mill in light winds. A pump used in connection with a windmill should be of smaller size than when operated by hand, for when hand pumping is resorted to, we want a pump which will elevate the maximum amount in the shortest time.

The requirements are different, however, in the use of windmills, for generally the windmill need not run but three or four hours a day to supply the tank with the necessary amount of water. During certain seasons of the year there are many days during which the wind is very light, in this locality in July and August. During these times the windmill should be under as light a load as possible in order that it may be certain to perform some work. Therefore a small pump, even though unable to furnish but half that which could be pumper by hand during the same period, will prove most satisfactory. This small pump will allow the windmill to work a great number of hours during light breezes, and will be found to pump more water during the twenty-four hours of a day than a larger pump would.

The character of the well and its depth should be known—whether it is a driven, drilled, or dug well; if drilled, the inside diameter of casing should be known; the height and distance through which water is required to be raised. This last dimension is taken from the water level in well to the base of the elevated tank. The amount of water entering well during dry seasons should be known, the capacity of tank to be used, and the height of tower necessary to raise wheel free from obstructions. All this information should be given the manufacturer when purchase is contemplated as they determine the cost of outfit, and allow an intelligent estimate to be made.

Gasoline Engines: Small gasoline, also kerosene, engines are now manufactured for the express purpose of doing pumping and other work about the farm. They have one distinctive advantage over other kinds of power, in that the water can be pumped in the quantities and at the time wanted, and the size of storage tank can be very accurately chosen. An engine can be selected which will burn natural gas, gasoline, kerosene, or alcohol. These engines do not require a great amount of skill to run them. They require little fuel and can be used for driving other light machinery when not needed for pumping water. Since there are many uses to which they can be put, it is well to select one of the many portable types now on the market, if gasoline or kerosene is to be the fuel used. They are mounted on skids or trucks and can be easily attached to churns, feed mills, corn shellers, grain fans, etc. For the sake of general utility, it is best to choose an engine of from 4- to 6-horse power. If only pumping is required or wanted, a 2- or 3-horse power engine will furnish ample power. With the advent of denatured alcohol, there is a possibility of a more economical fuel. A good 2- or 3-horse power engine can now be purchased at a cost of $80 to $100.

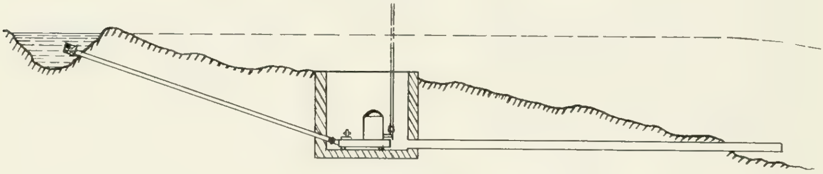
With any good, small, stationary gasoline engine working under favorable conditions, a fuel consumption as low as one pint of gasoline and 1.4 pints of alcohol per horse power hour may be reasonably expected, and the difference is slight with the well constructed engines now on the market. Any gasoline engine of the ordinary types can be run on alcohol fuel without any material change in the construction of the engine. The difficulties likely to be encountered are in starting and in supplying the correct amount of alcohol fuel, which is considerably larger than the quantity of gasoline required. The fuel consumption, which governs the cost of operation, depends chiefly upon the horse power at which the engine is being run and upon the setting of the fuel supply valve. It is easily possible to double the cost of fuel used, either by running the engine on a load below its full power or by a poor setting of the fuel supply valve.

On a dairy farm in Boone county a gasoline engine of 4-horse power pumps water from a nearby creek to a cistern on a hill, from which water flows to the house and barns by gravity. The owner operates engine a few hours twice a week, and states that the average fuel cost is only 15 cents per week, and that three dollars a year will cover the cost of repairs to pumping plant.

Hydraulic Rams: Where some means of pumping has to be used to furnish the water supply, probably the most economical method lies in the installation of a hydraulic ram. It can be used to fill the storage tank if the source of supply is a spring, flowing well, or running stream from which enough fall to supply the power can be obtained. In a proposed installation the first items to be considered are the supply and the available fall. Its use is practicable with a flow of only two gallons per minute and a fall of 18 inches. These are the lower limits and any increase in quantity and fall only betters conditions; increasing the amount pumped and the distance and height through which it can be elevated. The relation between the height of spring or supply, above the ram and the elevation to which the water is to be delivered, determines the proportion of water raised to that which runs to waste.

Water falling from higher to lower levels has energy in amount depending upon the distance it falls and the quantity falling. In the hydraulic ram this energy is made to pump and elevate water, thus utilizing to advantage that which otherwise runs continuously to waste. The power which operates the ram is created by the velocity of the water supplied to it, hence it necessary to have a fall or head of water the same as if a small water wheel was to be operated.

Fig. 5.



LOCATION OF HYDRAULIC RAM.

In operation, the ram is a combined pump and water motor, working in pulsations by a kind of water hammer caused by the abrupt stopping of the flow in the drive pipe. The energy the water has acquired is spent in forcing part of the water which drives it up into the tank or other reservoir through the delivery pipe.

The best locations for a ram are at the hillside spring, where the natural fall of the land furnishes a working head, or near a natural fall in a stream; leading supply from stream above falls to ram, and then letting it run back into stream below the falls. If spring is the source, the fall can be increased by walling in with brick or concrete, provided this does not materially decrease the flow. In the figure the natural fall is increased by placing ram in pit and letting waste water out through ordinary drain tile.

For the average farm house using say, 150 gallons per day, a ram which will operate on four gallons per minute will furnish the supply, and that too—through a thousand feet of pipe. It may be safely calculated that conveying water from 50 to 60 rods, one-tenth to one-fourteenth of the supplied water can be raised and discharged at an elevation ten times the fall. A rule given by one of the most prominent ram manufacturers reads thus: "To find the quantity of water which a ram will deliver, multiply the fall in feet from the spring to the ram, by the number of gallons per minute supplied to it; divide this product by twice the height to which the water is to be forced, and the result will be the quantity of water (in gallons) per minute delivered by the ram at point of discharge.

Appended is a table showing the sizes of rams now on the market and the approximate cost of same.

Hydraulic Ram Sizes.

Gal. per min. to operate.	Size of drive pipe in inches.	Size of discharge pipes in inches.	Price.
1½ to 4	1	½	$ 8.00
6 to 14	2	1	18.00
10 to 25	2½	1¼	25.00
20 to 60	4	2	45.00
30 to 120	6	2½	75.00

POSSIBILITY OF INTRODUCING PLUMBING INTO HOUSES ALREADY BUILT.

It goes without saying that plumbing can be put into a house more conveniently at the time the house is being built; but if this has not been done there is nothing to prevent its being installed afterward. Installing the plumbing may conflict with the household routine for a few days, but as all pipes should be run exposed for sanitary reasons, aside from cutting through ceilings and floors, little inconvenience is met with in putting the fixtures and pipes in place. A water back can be placed in almost any kitchen range and attached to a hot water boiler.

As an illustration of the cost of introducing such conveniences, some actual cases are cited. In an eight-room two-story house having in bathroom a lavatory, bathtub, and watercloset, one lavatory in bedroom; in kitchen a sink and 30-gallon range boiler; and in laundry one cold water faucet, these fixtures were set up with complete supply and waste pipe connections for $180.

In another six-room cottage employing an attic tank, water is supplied to bathroom fixtures, consisting of lavatory, bathtub, and watercloset, the kitchen sink and hot water heating tank, the total cost was $115.

Electric Pumping: There are many suburban residences on the outskirts of towns and villages to which the electric light mains have been extended, or could be very easily. If this condition prevails and advantage is taken of same for lighting the house; electricity can be made the power to do the water pumping. If an electric motor be used, the arrangement should be such that it will be automatic in its action. Whether the system be elevated-tank or pneumatic, it should be so arranged that the level of water in the elevated tank would not rise or fall below certain heights, nor the pressure in the pneumatic system vary more than a few pounds.

These pumps are rather attractive in appearance so would not be unsightly or take up much space if it were necessary to place it in the basement. Pump and motor are made in compact units either for belt or gear drive and operate practically noiseless. The size of the motor of course will depend upon the capacity of the pump; and the type, on the available current. Purchase of the whole unit had best be made from one firm, as motor and pump must be adapted to each other, and information as to the type of motor required gotten from the company furnishing electricity or from a local electrician.

A one-half horse power motor direct connected to a 2-inch by 4-inch cylinder pump has a capacity for ordinary lifts near 300 gallons per hour.

The first cost is comparatively large but the power cost and maintenance charges will probably be smaller than for any other except when hand power is used.

Conclusion: There are many modifications of the systems outlined, where soft and hard water piping is used, which are more or less complicated. In one of these hard water is supplied from a deep well and is used for laundry, kitchen and sanitary purposes, in the house, for watering stock and other outside purposes. The pneumatic tank is connected with a windmill or other pumping device, and is supplemented by a soft water tank in the basement. Water from the hard water tank is used to operate a water-lift which pumps from a cistern into the soft water tank in basement. This water lift is so constructed that when the pressure in the soft water tank equals the pressure in the hard water tank the lift will stop working and will not again start until water has been drawn off and the pressure reduced. Any system of this kind can best be worked out by a good plumber.

The requirements of no two families or homes are ever alike, but these suggestions are made with the hope that they may be a help in solving the question of water supply. The importance of sanitation and purity of supply have been emphasized, but none too strongly. The labor saved by having the water carried to the house, barn and garden will soon pay for the installation of some good system, while the value of the healthfulness secured by a supply of pure water and sanitary plumbing cannot be estimated in dollars and cents.

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SANITATION AND SEWAGE DISPOSAL FOR COUNTRY HOMES

BY

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SANITATION AND SEWAGE DISPOSAL FOR COUNTRY HOMES.

Introduction.—The demand for modernly equipped farm homes at a moderate cost is becoming an urgent one. Farmers throughout Missouri are striving to keep abreast of the times in modern methods of agriculture. Likewise they are seeking the latest and best practices in every line of activity pertaining to the industry of farming.

They are demanding that their homes be equipped with the same modern conveniences that the people of the city enjoy, and it is the call from them for information on modern farm sanitation that has led to the publication of this bulletin.

The greater part of the bulletin is devoted to the subject of modern sewage disposal plants for isloated houses. A portion has been given to the discussion of sewage disposal methods now employed on the farm, and still another portion to country plumbing.

It is the purpose of this bulletin to present several specific designs and to call attention to the necessity of home sanitation in a general way.

Sewage Defined.—Sewage is composed of the liquid and solid waste matter that flows through a sewer. The character of the foul matters thus carried off may be fecal, excretory, or of the nature of slop water.

The term as defined here may allude to the contents of the privy vault, dry earth closet, slop water basin, cesspool or the septic tank. Sewage may mean the contents of the cesspool, septic tank, etc., or it may refer to the waste material after its final deposit in a stream, ditch or upon a field. The term generally applied to sewage as it flows from the sewer to the final place of disposal is **effluent,** and should this word be found in subsequent pages of this bulletin it will be thus defined.

METHODS OF DISPOSAL.

The methods of sewage disposal may be conveniently divided into two general classes, namely: Water-Carriage Systems and Dry Sewage Systems. The latter will be taken up and discussed first, inasmuch as it is the one in more general use at the present time in rural communities.

Dry Sewage Methods.

Under this head two subdivisions of the subject will be made. They are **privy vaults** and **earth closets.** Both of these methods, though crude, can be made healthful and sanitary if proper care is taken in regard to their arrangement, location, and operation.

The Privy Vault.—The privy vault is the method most commonly used at the country home. This system will continue to be used for a long time on account of its cheapness and economy. Some suggestions are offered by which its sanitary conditions may be improved.

The privy vault as ordinarily constructed consists of a small frame building erected over a pit which receives the refuse or fecal matter. For a time such a receptacle is satisfactory, but unless properly cared for it becomes a nuisance, obnoxious both to sight and smell, as well as a menace to health. This obnoxious condition of privies can be avoided by a generous use of lime and an occasional removal of the waste from the pit.

Water Supply Contamination.—Occasionally a privy vault will be found near a well, cistern, or other source of water supply. This may become polluted, due to the seepage of the sewage through the ground. Furthermore this sewage waste may be so clarified by passing through the porous earth that by the time it reaches the neighboring source of water supply it will be clear and apparently pure. Expericence has taught us, however, that this water often contains disease germs which we have no means of detecting until we have been poisoned by them and have perhaps developed a case of serious illness.

Privy Vault Dangers.—Two of the common causes of the spread of typhoid fever are the contamination of the water supply, and the transmission of the disease by the ordinary house-fly. Instance after instance could be given where cases and even epidemics of typhoid fever have been caused by the pollution of wells or cisterns from neighboring privies which in some cases were located several hundred feet distant. The water in the wells was apparently pure and sparkling, yet it contained the germs of disease. Frequently a well or spring is polluted from a nearby brook or gully leading from a neighboring farm where recently there may have been a typhoid patient. Instances are on record where typhoid bacteria were transmitted a mile or two by this method. Hence too much precaution cannot be taken in the protection of the home water supply.

The privy vault often becomes a fly breeding place, and should therefore be as far as possible from the house. That flies do transmit disease, notably typhoid fever, there is no longer any doubt, and the privy vault should, as far as possible, be inaccessible to them. This may be accomplished by the use of screens. Another effective and inexpensive remedy for keeping the flies away from the closet is by a generous use of dry air-slaked lime applied daily.

Some precautions should be observed in connection with the building of privy vaults. Generally they should not be within one hundred feet of any source of water supply. Do not leave the excreta accessible to flies. Do not neglect the frequent removal of the waste material from the vault. If possible select the location of the privy vault so that the liquid waste will drain away from the premises into a ditch or gully rather than to have it pass near the cistern.

Earth Closets.—In connection with dry sewage systems we have the earth closet which is perhaps little used in this country, although employed to quite an extent in England. The earth closet is simple and cleanly and in many respects an entirely satisfactory substitute for the privy.

The excreta should be received in a box or pail made to fit closely beneath the seat. The seat may be like that of an ordinary water closet. Each time the closet is used a small amount of dry earth is added. The action of dry earth is to deordorize and render harmless the waste matter of the closet. The receptacle should be emptied frequently. The out-house or closet should be well lighted and ventilated, and preferably plastered on the inside. With proper attention, this closet need not be built far from the dwelling house.

The earth used in such a closet should be dry, and if possible, porous and of a loamy nature. A very sandy soil is useless. Ashes are entirely satisfactory for this purpose. Authorities on the subject of sanitation recommend the "Dry Closet" rather than the "Privy Vault," because it is far more sanitary and becomes less of a nuisance.

Regarding earth closets, Gerhard states the following in the annual report of the State Board of Health of Maine:

"All that is needed is a common closet, a supply of dry earth, a water tight receptacle beneath, and a convenient way of disposing of its contents at quite frequent intervals. The receptacle should be wholly above the ground, and may consist of a metallic lined box, or half of a kerosene barrel with handles on it for removal, or better still, a galvanized iron pail. The receptacle may be removed through a door in the back of the closet or in front of the seat, or by having the seat hinged and made to open backward it may be removed in that way.

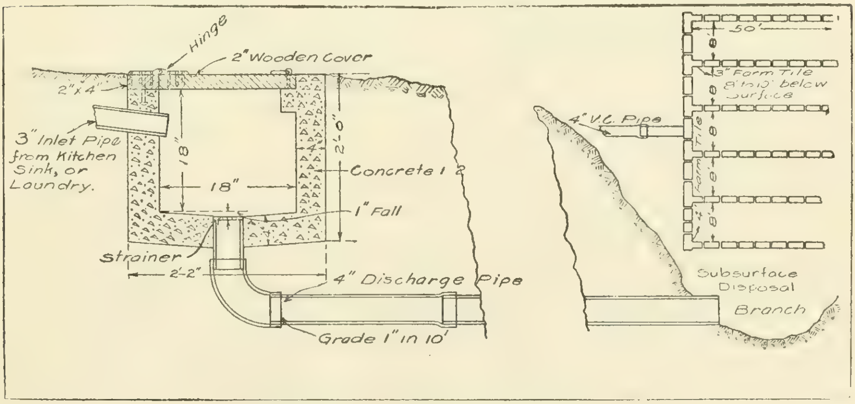
"The earth used should be common garden or field loam finely pulverized. Road dirt does well, but sand is not suitable. Coal ashes are also good. Whichever is used should be dry and screened through a sieve with about one-fourth inch meshes. The dry earth may be kept in a box set where it can be filled from the outside of the closet, or it is quite convenient to have one-half of the seat hinged, and beneath it a small compartment to hold the supply of earth. In this box there may be a small tin scoop which may be used for sprinkling over the refuse a pint or more of earth each time the closet is used. The main thing is to use enough earth to completely absorb all liquids. This last requirement of course precludes the throwing of slops into the closet."

A CONCRETE SLOP WATER DISPOSAL BASIN.

The Tank.—Fig. 1 shows an arrangement for the disposal of slop water from the kitchen or laundry. In many farm houses where it is impracticable to install a complete sewage system, such a convenience as the concrete basin shown will greatly reduce the labor of disposing of house slops. It is entirely sanitary, and may be used satisfactorily either winter or summer.

The basin tank for receiving the slops is made of concrete. The mixture should be in the proportion of 1:2:4, that is, one part of cement, two parts of sand, and four parts of broken stone. The thickness of the

FIG. 1.



Slop Water Disposal Basin.

walls should be four inches. The side walls should be vertical and the bottom should slope with a one-inch fall toward the center.

The size of the tank is 18″ wide x 18″ long x 18″ deep. A three-inch inlet pipe connects the tank to the kitchen sink or laundry. To aid in the escape of offensive gases from the tank the wooden cover is perforated with several holes. This does not entirely prevent the escape of gases through the opening of the sink, but if the tank and pipes are flushed occasionally little difficulty will arise from the escape of gas through the sink into the house.

A four-inch discharge pipe connects the tank to a ditch located at a distance not less than from fifty to one hundred feet from the house.

In case the ditch cannot be given sufficient slope for readily discharging the waste matter as it comes from the concrete tank it will be better to use the subsurface or underground method of disposal which will be described later.

The wooden cover is hinged as shown to a 2″ x 4″ piece of wood which is bolted to the concrete in a manner as indicated in the drawing. The cover rests on a concrete projection at the side, and for convenience in opening, a ring is attached. A strainer should be provided in the bottom of the tank as shown in Fig. 1. This strainer is to prevent the entrance of solid matter into the discharge pipe which might thus become choked.

Construction.—Excavate to a depth of two feet below the ground surface. The finished size of the excavation is to be 2′-2″ wide x 2′-2″ long x 2′ deep. Locate the inlet and the outlet pipes according to the measurements indicated on the drawing, Fig. 1, giving each pipe sufficient fall to provide for a ready drainage of the slop. Use the earth as one side of the form, the other side of the form being constructed of one-inch lumber properly braced. First lay the side walls, and after about thirty-six hours remove the forms. Then lay the concrete in the bottom and carefully plaster the inside throughout. If crushed rock cannot be had, creek sand and gravel may be used with entirely satisfactory results. The concrete should be rammed into place.

Disposal of the Outflow.—The discharge from the above slop basin may be emptied directly into a running stream, or into a ditch some fifty to one hundred feet from the house. It will soon be purified and no offensive odors will form from it. The respective sizes of the inlet and discharge pipes should be three inches and four inches. They should be vitrified clay pipe with cemented joints. The slop tank should be fifteen to twenty feet from the house. The slope of the inlet pipe should be greater than the slope of the outlet pipe. A slope of one foot in fifty feet for the outlet pipe is desirable in order that it may be cleansed by the velocity of flow.

Subsurface Disposal of the Waste.—It is not possible in every case to dispose of the waste water as explained above. Should the ground be very flat, no ditch being available, other methods of disposal must be resorted to; chief among them being **subsurface** irrigation or disposal. In a subsurface disposal system a 3″ open-jointed drain tile is used, laid with ¼ to ½ inch open joints, and to a slope of one inch in twenty-five feet. It is very essential that the tile be laid to a uniform slope. If possible the ditch should be excavated eight to twelve inches below the pipe and filled with sand, gravel, cinders, or other porous material, to aid in the immediate filtration of the waste water.

The tile should be laid from eight to twelve inches below the surface of the ground. It is essential that the drain tile be as near the surface of the ground as possible in order that the waste water may be purified by the oxygen which is present in the surface layers of the earth. At a greater depth this purifying process is greatly retarded due to the absence of oxygen. Should the ground be of a compact or clay nature, a greater length of drain tile will be necessary, as also there will be greater need for the porous material beneath the tile.

The approximate cost of such a slop water disposal system is given below. If the waste water is emptied into a ditch or running stream the cost of slop basin will be $5.85 as shown below. If the subsurface disposal scheme is used, then an addtional 50 feet of 3″ pipe drain tile will be required. Fifty feet of drain tile at three cents per foot will add $1.50 to the cost, making a total cost of $7.35.

Approximate Cost—Labor not Included.

Cement, two sacks at 40c	$ .80
Hinges	.25
Ring	.10
Sixty-five feet of vitrified clay pipe at 6c	3.90
Wooden cover	.25
4″ elbow	.35
3″ elbow	.30
Total	$5.85

CESSPOOLS.

The general definition of a cesspool is a tank into which the house sewage is discharged, said tank retaining the solid and sometimes the liquid matter until removed. There are two types of cesspools, viz., **leaching** and **tight** cesspools.

The leaching cesspool is built of loose brick or stone without the use of cement or mortar. Through the crevices in the side of the cesspool the liquids leach out into the surrounding soil leaving the solid matter to remain in the cesspool until removed by pumping or by similar means.

The tight cesspool is built of brick or concrete, it being essential that the cesspool be water tight. The liquid is removed by being drained out through a drain pipe. The solids are removed as in the leaching cesspool.

The writer quotes from the following authorities in regard to the unsanitary conditions of cesspools.

"Sparkling water may not be pure. It may contain typhoid germs. The filtration of sewage effluent does not purify it although it may clarify it. It requires the action of oxygen and light to render sewage harmless." —Burton T. Ashley.

"It is hopeless to depend upon the purifying influence of intervening soil to protect the wells from cesspool fouling, because soil filtration, in order to be effective must be intermittent."—Mason.

"The cesspool is a relic of medieval shiftlessness and carelessness for which no excuse can be offered."—Dr. Bashore.

"The privy or cesspool is walled with loose stone so that the liquid waste may leak through them into the surrounding soil. The result of this is a gradual increasing pollution of the soil and often a neighboring spring or well becomes so contaminated as to spread disease."—Prof. Merriman.

THE SEPTIC TANK.

The modern septic tank, sometimes called a scum tank or putrefaction tank, consists essentially of a water tight chamber of suitable capacity, through which the sewage flows slowly, and almost continuously, the inlets and outlets being submerged to prevent an undue disturbance of the surface scum.

Countless numbers of bacteria harbored in the surface scum and living upon the solids in the sewage, cause its liquefaction. All solids settle to the bottom of the tank from which they are removed at frequent intervals.

Septic Tank Effluents.—While the liquid waste from the septic tank contains but little solid matter, it is highly charged with putrescible matter in solution, and the liquid gives off bad odors, particularly on warm or damp days. It cannot be sufficiently emphasized that the septic tank process is only a preliminary process of sewage treatment, that the waste from septic tanks are neither clarified, nor purified, that they contain all the dissolved organic substances which are the chief causes of contamination of lakes and streams, and that a further purification in most cases is necessary.

Operation of Septic Tanks.—No septic tank shows good results when first put in operation. It is necessary that the process be carried on for several weeks before it becomes efficient. The claims that all suspended impurities are liquefied and that there will be no increase in the deposit of solids or in the scum in a septic tank have not been realized. On an average only from thirty to fifty per cent of the suspended solid matter is destroyed, partly by liquefaction and partly by changing them into gas.

Capacity of Septic Tanks.—The capacity of the septic tank should be made in size about three-fourths the daily volume of the sewage. Otherwise the tank acts as a mere settling chamber. On the other hand the tank should not be too large, as the sewage remains too long in the tank. By the use of two tanks in series the capacity of each tank may be reduced.

Open and Closed Septic Tanks.—For isolated buildings it is preferable to use covered tanks, notwithstanding the fact that open tanks have been found to be quite satisfactory. Reasons for this are: that bad odors are confined within the tank; the sewage scum is concealed from sight; the surface of the sewage in the tank is protected from wind, rain and snow; but most important of all, the probable infection of food in the house by flies is prevented.

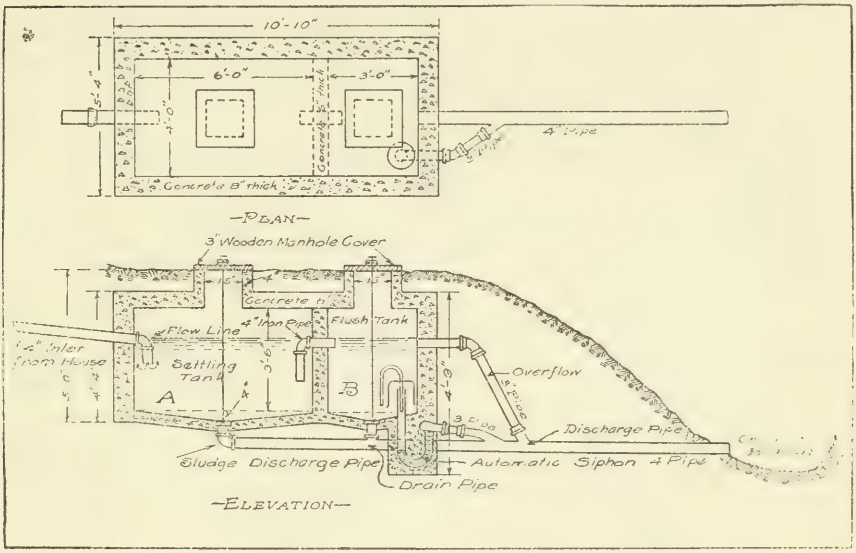
Small Concrete Septic Tank.—Fig. 2 shows a concrete septic tank which is designed large enough to provide for the sewage disposal of a family of six.

The tank operates as follows: Sewage enters tank 'A" through a four-inch inlet pipe from the house. A heavy scum will form over the surface of the liquid, and beneath this scum the sewage is liquefied by the action of the bacteria which develop or grow in the surface scum. For the successful growth or culture of these bacteria, the scum must not be frequently broken or disturbed, hence the inlet pipe is made to discharge below the surface of the liquid. For the same reason the overflow pipe from tank "A" to tank "B" is extended below the surface to about the middle of tank "A" where the liquefaction of the sewage is most complete.

In the sludge discharge pipe provision is made for cleaning out the sludge from the settling tank without putting it out of service, and, furthermore, provision is made for the discharge of the contents of the tank during a time when it may be found necessary to repair the siphon.

After passing through the flush tank the sewage may be discharged directly into a creek or a running stream. Under most conditions, if a running stream were not available, the effluent may be discharged into a ditch or other drainage branch which should be seventy-five or one hundred yards from the house. No offense from odor will ordinarily be given from such a system of disposal, as there will usually be enough rain during the year to flush the small creek or ditch into which the waste enters.

FIG. 2.



Small Concrete Septic Tank.

When the effluent is discharged direct into a running stream of sufficient flow the tank "B" may be omitted. If the waste is treated by subsurface irrigation, then the flush tank "B" should always be used in order to have the sewage delivered intermittently. If the flow be continuous upon the ground then sufficient time is not given to allow the air to enter the soil, and consequently it soon becomes water-logged.

A six-inch partition should separate settling tank "A" from flush tank "B." The liquefied sewage flows from tank "A" from flush from which it is removed by means of an automatic siphon, which is so designed that it will discharge when the sewage reaches a certain height in the flush tank. This siphon should be so arranged that it will discharge the liquid twice every twenty-four hours. This siphon action will take place when the tank is receiving a flow of three hundred and sixty gallons per day.

To provide for the entrance of air into tank "B," which is necessary for the successful operation of the siphon, and also to provide for an overflow of the sewage in case the siphon becomes clogged and refuses to discharge the contents of tank "B", an overflow pipe is connected to the main discharge pipe as shown in Fig. 2.

A valve is placed in the bottom of the flush tank "B" to provide for the removal of sediment which in time may collect there.

The cost of the above septic tank, not including labor, is as follows:

Cement, 22 sacks at 40c per sack	$ 8.80
175 ft., 4″ V. C. pipe at 8c per foot	14.00
10 ft., 3″ V. C. pipe at 6c per foot	.60
Automatic siphon	15.00
Incidentals	5.00
Total	$43.40

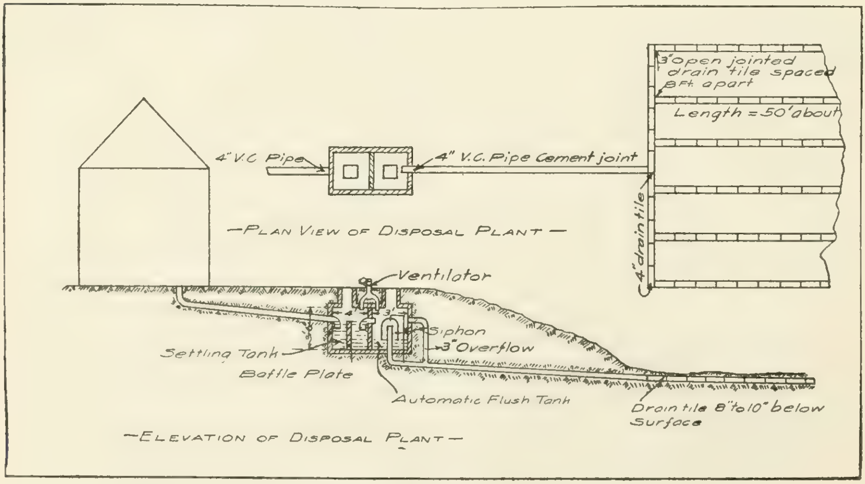
As will be noted above no estimate of the cost of sand or gravel has been made. In most farming communities this may be obtained from creeks or branches nearby at the expense of hauling.

SUBSURFACE DISPOSAL OF SEWAGE.

In septic tank disposal sewage systems, as in all others of whatever nature they may be, some provision must be made for the effluent after it leaves the tank. If it is allowed to flow out upon the ground continually a nuisance will soon be created, which may endanger health. In the absence of running streams into which to empty it, some other means of disposal must be resorted to. Perhaps the one of universal application is the **subsurface disposal scheme.** This plan may be successfully used whether the ground be level or sloping. In fact it is about the only method that may be used in a flat country.

Subsurface disposal means the disposal of the liquid sewage through a system of open-jointed drain tile laid from eight to twelve inches below the surface of the ground. The open joints should be from one-fourth to one-half inch apart, covered with some material to prevent loose earth from falling back into the pipe during the backfilling of the ditch. The length of the drain pipe will depend upon the amount of sewage and character of the soil. An intermittent discharge is essential, hence the necessity of an automatic siphon. For the lateral drains a three-inch tile is ordinarily used.

FIG. 3.


3″ open jointed drain tile spaced 8 ft. apart
Length = 50′ about
4″ V.C Pipe
4″ V.C. Pipe Cement joint
4″ drain tile
—PLAN VIEW OF DISPOSAL PLANT —
Ventilator
4′
3′
Siphon
3″ Overflow
Settling Tank
Baffle Plate
Automatic Flush Tank
Drain tile 8″ to 10″ below Surface
—ELEVATION OF DISPOSAL PLANT —

Subsurface Disposal Plant.

It is evident that such a system of disposal requires the effluent to be a liquid, otherwise the drain tiles would soon become clogged and stop the operation of the plant.

Design of the Subsurface Disposal Plant.—Fig. 3 shows the arrangement of a typical subsurface disposal system. The plan view illustrates the method of arranging the drain tile. The distance of the septic tank from the house is about one hundred feet, and from the septic tank to the disposal field approximately one hundred feet. Local conditions will govern entirely as to the location of the tank and the disposal ground. In no case should the tank be closer to the house than one hundred feet.

Construction.—The pipe connecting the septic tank to the house should be a four-inch vitrified clay pipe, with bell and spigot joints carefully cemented. The four-inch pipe connecting the two tanks is to be arranged as shown in the drawing, Fig. 3.

The pipe line connecting the flush tank with the disposal ground is to be a four-inch V. C. pipe with cemented joints, and laid to a grade of at least one-fourth inch to the foot.

The main transverse drain tile should be four inches in diameter laid level with cemented joints. It is necessary that this tile be laid level in order to secure an equal distribution of the sewage to the laterals. The lateral drains should be three inches in size, laid in rows about fifty feet long and eight feet apart, and laid to the grade of one inch in twenty-five feet.

For a family of six people from 150 to 200 feet of drain tile will be necessary in a loose soil. In a compact clay soil, a much greater length will be needed, probably 300 to 400 feet.

Septic Tank.—The septic tank shown here consists of a settling tank and a flush tank provided with an automatic siphon. For the details of construction see Fig. 2.

Approximate Cost of Septic Tank.

Cement, 22 sacks at 40c	$ 8.80
100 ft. of 4″ V. C. pipe at 8c	8.00
10 ft. of 3″ V. C. pipe at 6c	.60
40 ft. of 4″ drain tile at 4c	1.60
150 ft. of 3″ drain tile at 3c	4.00
Automatic siphon	15.00
Incidentals	5.00
Total	$43.00

SURFACE DISPOSAL OF SEWAGE.

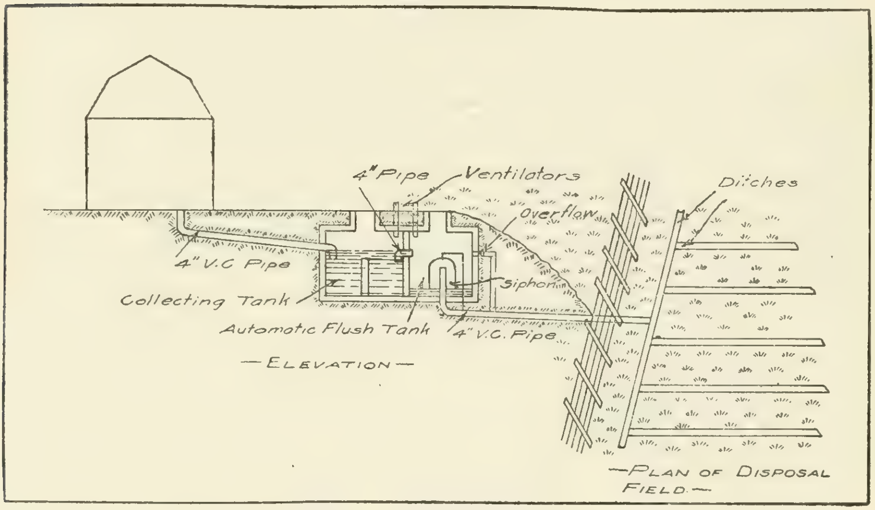
The surface disposal problem for sewage is solved in various ways. As in the case of the subsurface disposal scheme, it is essential that the sewage be discharged upon the surface of the ground intermittently. Such an arrangement gives time for the purification of the soil, which would soon become water-logged if the flow of sewage upon it were continuous.

Fig. 4 shows a typical surface disposal plant. The operation of the septic tank used is identical with that of Fig. 2, the only change being in the method of the final disposal of the discharged sewage. See Fig. 2 for the details of the construction of the septic tank.

The Disposal Field.—This plot of ground may be a small patch of cultivated land with a growing crop, such as corn, or it may be a piece of meadow or pasture land. A plot containing 2500 square feet will be ample to take care of the sewage from a family of six. This plot of ground should be at least 200 feet from the house or well, or any source of water supply. Upon reaching the disposal field the sewage empties into a ditch about one foot wide and four inches deep running at right angles to the disposal pipe from the septic tank.

Distributing Ditches.—The distributing ditches may be from four feet to six feet apart, and four inches deep by eight inches wide. Their length will depend upon the size of the available disposal plot. There should be a sufficient number of ditches to quickly and equally distribute the sewage over the field.

FIG. 4.



Surface Disposal Plant.

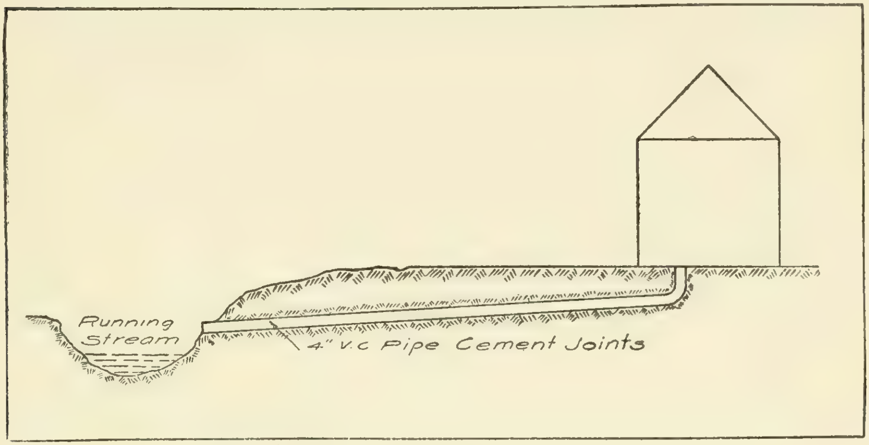
Estimated Cost.

Cement, 22 sacks at 40c	$ 8.80
100 ft. V. C. pipe at 8c	8.00
10 ft. V. C. pipe at 6c	.60
Automatic siphon	15.00
Incidentals	5.00
Total	$37.40

DIRECT DISPOSAL SYSTEM.

In some cases it may be advisable to dispose of the sewage directly into a running stream, but this plan is not to be generally recommended as the best. The danger is that the water farther down the stream sometimes used for drinking purposes may become contaminated, or the supply water for stock may be so fouled as to become unfit for use. If the flow of the stream be large, the dilution will be so great that little danger will occur from its contamination by the sewage of a single farm house. Disease germs may be transmitted for a distance of several miles, hence there is always danger in using for drinking purposes any water from a river into which sewage empties.

FIG. 5.



Direct Disposal Plant.

Fig. 5 shows an arrangement for the disposal of sewage direct into a stream. The discharge pipe should have a uniform slope of about one foot in twenty-five feet to insure its proper flushing.

Estimating the Cost.—The cost will obviously depend upon the distance of the house from a nearby creek. The disposal pipe should be a four-inch vitrified clay pipe and will cost eight cents per foot. The cost may be estimated for any specific design in hand from the general cost data given below, including cement, sewer pipe, drain tile, and concrete.

Cement 40c per sack, net.
Sewer pipe, 3″, 6c per foot.
Sewer pipe, 4″, 8c per foot.
Sewer pipe, 6″, 11c per foot.
Sewer pipe, 8″, 20c per foot.
Elbows, ¼, ⅛, and 1-16 bend.—
    3″ 30c each.
    4″ 35c each.
    6″ 45c each.
    8″ 60c each.
Y's and T's.—
    3″ 35c each.
    4″ 45c each.
    6″ 70c each.
    8″ 90c each.
Traps.—
    3″ 65c each.
    4″ 75c each.
    6″ $1.00 each.
    8″ $1.60 each.

Drain Tile.—

3″	3c per foot.
4″	4c per foot.
6″	6c per foot.

Concrete.—On an average concrete for the above construction will cost from five to seven dollars per yard where it is necessary to hire all labor and buy all materials. One barrel of cement (about four sacks) will in general make one cubic yard of concrete consisting of a 1:2½:5 mixture.

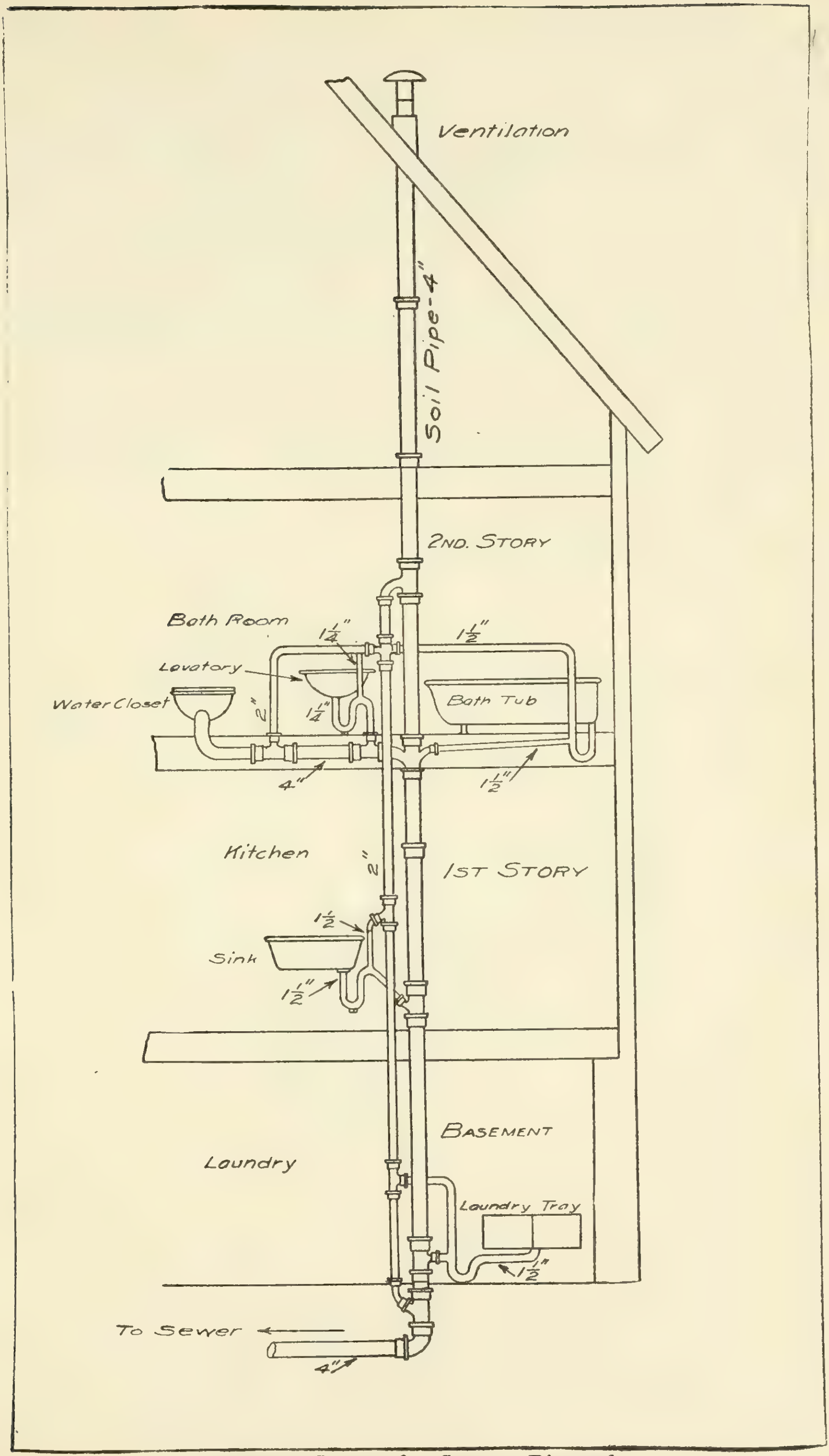
PLUMBING.

Fig. 6 shows the plumbing of the bath-room, kitchen and laundry of a modern house. The plumbing necessary for carrying the sewage to the main sewer outside of the house is also shown in the drawing. It will be noted that the system is fully vented so that no trouble will be had from the escape of sewer gas into the house.

The fixtures usually placed in the bath-room are the bath tub, wash basin, and the water closet; in the kitchen, a sink, and in the basement a laundry tray or tub.

The main ventilation or soil pipe, as it is commonly called, should pass upward through the roof to the open air. Its purpose is to relieve the gas pressure which might otherwise force the traps and enter the house. The top of the soil pipe should be covered with a cap to prevent the entrance of rain or snow.

FIG. 6.



Plumbing System for Sewage Disposal.

Cost.—The cost of the plumbing will depend upon the quality of the fixtures installed. For a two-story seven-room house fitted with first-class plumbing and fixtures throughout, the cost will be about $165. This cost item includes the following: Bath tub, wash basin, water closet, kitchen sink, laundry tub, a forty gallon hot water heater in the kitchen, all the necessary water piping to bath room, laundry and kitchen, and all the necessary drain tile and sewer pipe completely installed ready to connect with the main sewer located outside a few feet away from the house.

The expense item of $165 mentioned above includes the cost of both labor and material. We may add to this sum $50 for the septic tank and sewer pipe outside of the house, giving a total cost of $215. This estimate does not include the cost of a supply tank for water, nor the cost of putting in the water supply pipes. The water supply is described in a bulletin: "Water Supply for Country Homes," which may be obtained by addressing the Director, Missouri Engineering Experiment Station, Columbia, Missouri.

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THE HEATING VALUE AND PROXIMATE ANALYSES OF MISSOURI COALS

BY
C. W. Marx
Paul Schweitzer
(A Reprint)

UNIVERSITY OF MISSOURI
COLUMBIA, MISSOURI
March, 1911

3,000

The Engineering Experiment Station of the University of Missouri was established by order of the Board of Curators July 1, 1909.

The object of the Station is to be of service to the people of the State of Missouri.

First: By investigating such problems in Engineering lines as appear to be of the most direct and immediate benefit and publishing these studies and information in the form of bulletins.

Second: By research of importance to the manufacturing and industrial interests of the State and to Engineers.

The staff of the Station consists at present of a Director and two research assistants together with a number of teachers who have voluntarily undertaken research under the direction of the Station.

Suggestions as to problems to be investigated, and inquiries will be welcomed.

Any resident of the State may on request obtain bulletins as issued or if particularly interested, may be placed on the regular mailing list. Address the Engineering Experiment Station, University of Missouri, Columbia, Missouri.

HEATING VALUES AND PROXIMATE ANAYLSES OF MISSOURI COALS.

C. W. MARX, Professor of Mechanical Engineering (1893-1901).
DR. PAUL SCHWEITZER, Professor of Chemistry (1872-1909).

Introductory Note:—This bulletin is a reprint of a report upon the properties of Missouri coals made about ten years ago by Prof. C. W. Marx, then Professor of Mechanical Engineering, University of Missouri, in collaboration with Dr. Paul Schweitzer, who was at that time Professor of Agricultural Chemistry. As this report contains information relative to the characteristics of Missouri coals not published elsewhere it has been decided to republish it in an Engineering Experiment Station Bulletin in order that it may continue to be of value and available for the use of the citizens of the State.

During the fall and winter of 1900-1901 the writer undertook a systematic investigation of the coals mined in Missouri. All the samples, save one, were cut from the face down through the entire thickness of the vein. A sample of about forty pounds thus collected from each mine was carefully sampled down to fill a Mason quart jar which, properly sealed, was taken without delay to the Experiment Station Laboratory where all analytical work including heat values by the bomb calorimeter was done. The calorimeter results have been calculated on the basis of the coal as taken from the mine to be burned.

The value of a fuel depends upon the number of heat units that it will produce and is usually measured in number of pounds of water that one pound of such fuel will evaporate or convert into steam. This is called its calorific value and is really the value for steam boiler purposes obtained per pound of coal.

Although coal is the most important mineral of Missouri, no thorough and complete investigation of the calorific values of her coals has hitherto been made, so far as is known. The two Departments of the State University above mentioned have undertaken, therefore, such an investigation and now print a report of the same. Professor Marx visited every mine mentioned, took the samples in person at the face, except in the case of sample No. 7. On account of the lateness of the hour and the condition of the entrance to the mine this sample was picked from a car that seemed to have been loaded during the day.

EXPLANATION OF TERMS.

A heat unit is the quanity of heat required to raise the temperature of one pound of water, at its maximum density, one degree Fahrenheit. The expression from and at 212 degrees F. means that the water

I.—TABLE SHOWING CALORIFIC VALUE OF MISSOURI COALS.

Rank.	Name of Mine.	County.	Location.	Thickness of vein in inches.	Heat units per pound of coal.	Pounds of water evaporated from and at 212° F. per lb. of coal. Boiler efficiency 60%.
1	No. 8, Western Coal Co.	Barton	Near Minden Station	36	13763	8.55
2	No. 3, Weir Coal Co.	Barton	Near Vernon Station	36	13759	8.55
3	Brush Creek Coal Co. Upper Vein	Jackson	3 miles Southeast of Kansas City	16	13710	8.52
4	No. 14, Central Coal and Coke Co.	Bates	5 miles South of Rich Hill	60-66	13500	8.38
5	Rush Coal Co.	Bates	5 miles South of Rich Hill 1½ miles West of previous one	42	12824	7.96
6	Keene	Boone	4½ miles North of Columbia	44	12780	7.94
7	Thompson	Henry	1 mile East of Deepwater		12757	7.92
8	Henry	Boone	Switzler	42	12492	7.76
9	Cooper Creek Coal Co.	Henry	3½ miles Southeast of Deepwater	32-42	12326	7.66
10	Kingston	Caldwell	1 mile North of Kingston	12-18	12292	7.63
11	Caldwell Coal Co.	Caldwell	2 miles East of Hamilton	18-20	12115	7.52
12	Bowen Bros.	Henry	½ mile Northeast of Louis Station	30	12093	7.51
13	Watkins	Henry	1½ miles Southeast of Clinton	21	12090	7.51
14	Excelsior	Lafayette	½ mile West of Higginsville	16	12010	7.46
15	Vernon Coal Co.	Bates	2½ miles Southeast of Rich Hill	36-60	11978	7.44
16	Marceline Coal Co.	Linn	½ mile South of Marceline	28	11939	7.41
17	Murlin Coal Co.	Adair	½ mile North of Stahl	48	11854	7.36
18	No. 15, Rich Hill Coal Co.	Bates	2 miles South of Rich Hill	48	11834	7.35
19	Edmonds	Lafayette	¼ mile East of Waterloo	18	11829	7.35
20	No. 6, Farmers' Consolidated	Lafayette	1 mile West of Higginsville	16	11824	7.34
21	No. 66, Kansas & Texas Coal Co.	Macon	3 miles South of Bevier	56	11769	7.31
22	Silver Creek Coal Co.	Lafayette	¼ mile West of Waverly Station	48	11764	7.30
23	Elliott Coal Co.	Randolph	Elliott Station	48	11676	7.21

24	Buckhorn Coal Co.	Lafayette	1 mile West of Waverly Station	48	11643	7.23
25	No. 10, Morris Coal Co.	Randolph	1 mile East of Huntsville	48	11642	7.23
26	No. 70, Kansas & Texas Coal Co.	Macon	4½ miles Southwest of Excello	54	11626	7.22
27	Murlin Coal Co.	Ray	Fleming Station	22	11583	7.19
28	Salt Fork Coal Co.	Lafayette	½ mile East of Corder	22	11580	7.19
29	Jones & Davis	Randolph	3 miles West of Moberly	48	11574	7.19
30	Brush Creek Coal Co. Lower Vein	Jackson	3 miles Southeast of Kansas City	24	11524	7.16
31	No. 1, Higbee	Lafayette	½ mile West of Higbee	44-48	11522	7.15
32	Labor Exchange	Lafayette	1¼ miles West of Wellington	18	11492	7.14
33	No. 1, J. C. McGrew	Lafayette	3½ miles West of Lexington	22	11395	7.08
34	Emporia	Putnam	1¼ miles North of Unionville	36	11390	7.07
35	No. 61, Kansas & Texas Coal Co.	Macon	2 miles Southwest of Bevier	51	11372	7.06
36	Richmond & Camden Coal Co.	Ray	1 mile West of Camden	20	11331	7.04
37	No. 11, Richmond & Camden Coal Co.	Ray	1 mile West of Richmond	24	11322	7.03
38	No. 8, Mendota Coal Co. Missouri City Coal Co.	Putnam Clay	½ mile South of Mendota Station. Missouri City	36 22	11274 11274	7.00 7.00
39	No. 14, Richmond & Camden Coal Co	Ray	¼ mile South of Richmond	24	11250	6.99
40	Corder Coal Co.	Lafayette	¾ mile West of Corder	22	11233	6.98
41	Glen Oak, Lexington Coal Co.	Lafayette	4 miles Northeast of Lexington	24	11220	6.97
42	Valley Mine, Lexington Coal Co.	Lafayette	1½ miles South of Lexington	22	11209	6.96
43	North Western Coal Co.	Macon	1 mile South of Bevier	42-48	11191	6.95
44	No. 2, Higbee	Lafayette	2 miles East of Higbee	42	11147	6.92
45	Dover Coal Co.	Lafayette	1 mile East of Dover Station	18	11018	6.84
46	Rombauer	Adair	½ mile West of Novinger	43	10877	6.77
47	Carter	Lafayette	1½ miles East of Wellington	20	10770	6.69
48	Graddy-Lexington Coal Co.	Lafayette	3 miles West of Lexington	20	10759	6.68
49	Grundy Coal Co.	Grundy	½ mile Southeast of Trenton	18	10704	6.65
50	J. B. Seitz	Lafayette	¾ mile West of Waterloo	18	10664	6.62
51	No. 2, Mendota Coal Co.	Putnam	2 miles Southeast of Mendota Sta.	34	10623	6.60
52	Mayview Coal Co.	Lafayette	Near Mayview Station	18	10458	6.50
53	Blackbird	Putnam	3 miles Northeast of Unionville	34	10437	6.48
54	Lingo	Macon	Opposite Lingo Station	36-42	10224	6.35

is taken in at a temperature of 212 degrees Fahrenheit and evaporated at atmospheric pressure. Thus all the heat is used to evaporate the water. This is merely an arbitrary standard used in boiler-testing.

In table I, the column headed heat units per pound of coal is the maximum number of heat units that one pound of coal will yield when burned in a furnace where there are no losses of any kind. The number of pounds of water that a pound of coal will evaporate from and at 212 degrees F. depends upon the efficiency of the boiler and furnace. The efficiency of boilers in our western states with the ordinary furnace and setting generally varies from 50 per cent to 60 per cent, but in a great many cases it is far below 50 per cent. With mechanical stokers, uniform duty, well designed boiler, and well designed furnace, an efficiency of 70 per cent is easily maintained. Assuming a boiler efficiency of 60 per cent the last column in table I was computed. It shows the number of pounds of water that one pound of the various coals would evaporate under favorable conditions with such an efficiency (60 per cent), the water being taken in at 212 degrees F. and evaporated at atmospheric pressure.

Table I shows the rank of the coals arranged according to their calorific value.

Table II shows the same coals according to their rank as in table I with their proximate analyses. These proximate analyses were made according to accepted methods. All coals were analyzed and tested in duplicate. Since some of the coals showed the presence of gypsum, it was deemed best not to subtract the sulphur found from the volatile matter and from the fixed carbon as is usually done.

The last column in table II shows how far the calorific value of a coal is dependent upon the amount of the volatile matter and fixed carbon. A study of this column will show that with few exceptions the sum of these two percentages seems to determine the rank of the coal, the same as the calorific value did in table I.

It is not claimed that the calorific values, as obtained and tabulated on a basis of 60 per cent boiler efficiency, are the real measures of the heating values of the various coals, but merely indices thereof and aids to a comparative estimate only.

The only way to obtain these real values for different coals at any given steam plant is to burn equal quantities of them under the same boiler, all conditions being the same for all the tests. The coal that is most economical for one steam plant under its peculiar conditions is not necessarily the most economical for another, on account of the furnace, grate area, etc. In addition to testing the coals by burning them under a boiler and determining the number of pounds of water evaporated per pound of coal, a record of the proximate analyses should be kept, in order to establish a standard of quality in making future purchases. Such a record will show that coals, ranging between certain percentages in volatile matter, moisture, fixed carbon, ash, and sulphur, are the more economical.

Sulphur occurs in coals as sulphide of iron, commonly known as iron pyrites, and sulphate of lime, usually known as gypsum. The sulphur is an index of the clinker-forming property of a coal since it assists in the fusing of the ash.

The heating value of a coal, depending chiefly upon the per cent of fixed carbon, and less upon the per cent of volatile matter, is materially affected by the per cent of ash, moisture and sulphur in the form of gypsum. These precentages vary with individual mines and with different places in the same mine. The amount of ash in the commercial product depends in great measure upon the care taken at the mines in cleaning it before shipment. The evaporating capacity of a boiler having a given number of square feet of heating surface and grate area, depends primarily upon the number of heat units generated in the furnace. The greater the number of heat units a given coal produces per pound, the greater will be the number of pounds of water evaporated per pound of coal burned under this boiler.

If a coal contain a large per cent of moisture and hydrogen, not only will the number of heat units derived be reduced by evaporating this moisture present and formed, but also by heating this aqueous vapor to the temperature of the chimney, all of which heat escapes and in no way serves to furnish heat to the boiler.

If a coal is high in the percentage of ash, not only will its heat value be diminished, but the quantity of ash and clinker resting upon the grate bars will tend to reduce the draft area and hence will prevent perfect combustion. Moreover the gases which would otherwise burn and produce heat with a proper air supply are in danger of escaping unburned. A coal high in content of ash demands a stronger draft and a larger grate area than one with a lower content. A boiler designed with a furnace to burn a coal with a low percentage of ash will give very unsatisfactory results with a coal having a large percentage of ash, and vice versa. In other words, a boiler furnace should be designed as nearly as possible for a given quality of coal, from which it is evident that with a given grate area the quality of the coal determines in a great measure the capacity and economy of a boiler.

II.—TABLE OF PROXIMATE ANALYSES OF MISSOURI COALS.

Rank.	Name of Mine.	Water Per cent.	Volatile matter per cent.	Fixed carbon per cent.	Ash per cent.	Sulphur per cent.	Volatile matter plus carbon.
1	No. 8, Western Coal Co.	2.35	35.73	53.72	8.20	4.10	89.45
2	No. 3, Weir Coal Co.	3.62	34.40	53.98	8.00	4.02	88.38
3	Brush Creek Coal Co.	10.30	40.04	45.35	4.31	2.35	85.39
4	No. 14, Central Coal Co., Upper Vein	2.02	40.80	46.39	10.79	6.57	87.19
5	Rush Coal Co.	4.07	41.05	43.22	11.66	3.38	84.27
6	Keene	6.17	40.83	45.04	7.96	3.72	85.87
7	Thompson	8.95	34.75	51.28	5.03	1.11	86.03
8	Henry	9.62	38.50	45.63	6.25	2.78	84.13
9	Cooper Creek Coal Co.	7.24	34.60	48.10	10.06	2.64	82.70
10	Kingston	10.63	38.58	44.03	6.76	2.54	82.61
11	Caldwell Coal Co.	9.26	36.69	43.56	10.49	3.61	80.25
12	Bowen Bros.	6.65	40.27	40.68	12.40	4.67	80.95
13	Watkins	8.10	36.13	45.02	10.75	4.72	81.15
14	Excelsior	10.25	36.10	44.69	8.96	3.54	80.79
15	Vernon Coal Co.	6.34	35.89	44.47	13.30	4.81	80.36
16	Marceline Coal Co.	9.45	33.25	47.27	10.03	5.73	81.52
17	Murlin Coal Co.	14.78	39.10	42.44	3.68	2.16	81.54
18	No. 15, Rich Hill Coal Co.	5.88	35.20	44.72	14.20	4.83	79.92
19	Edmonds	9.55	35.23	46.42	8.80	3.15	81.65
20	No. 6, Farmers' Consolidated	11.95	36.14	44.70	7.21	2.57	80.84
21	No. 66, Kansas & Texas Coal Co.	12.00	39.10	41.83	7.07	3.44	80.93
22	Silver Creek Coal Co.	8.34	37.68	41.34	12.64	5.28	79.02
23	Elliott Coal Co.	11.15	36.32	42.77	9.76	3.55	79.09
24	Buckhorn Coal Co.	8.58	38.20	42.04	11.18	4.90	80.24
25	No. 10, Morris Coal Co.	9.90	31.73	47.33	11.04	2.86	78.06
26	No. 70, Kansas & Texas Coal Co.	10.20	36.26	43.16	10.38	4.47	79.42

27	Murlin Coal Co.	13.07	37.85	41.66	7.42	1.92	79.51
28	Salt Fork Coal Co.	11.88	35.76	43.64	8.72	3.76	79.40
29	Jones & Davis	11.05	36.87	41.65	10.43	6.56	78.52
30	Brush Creek Coal Co., Lower Vein	7.85	33.18	44.17	14.80	5.05	77.35
31	No. 1, Higbee	10.00	29.99	50.77	9.24	3.57	80.76
32	Labor Exchange	12.31	35.91	43.58	8.20	1.71	79.49
33	No. 1, J. C. McGrew	15.02	34.20	43.20	7.58	2.97	77.40
34	Emporia	17.48	36.01	42.40	4.11	2.38	78.41
35	No. 61, Kansas & Texas Coal Co.	12.12	37.43	41.30	9.15	3.74	78.73
36	Richmond & Camden Coal Co.	9.83	37.93	42.99	9.25	3.21	80.92
37	No. 11, Richmond & Camden Coal Co.	11.97	36.36	41.65	10.02	4.36	78.01
38	No. 8, Mendota Coal Co.	17.29	37.19	41.43	4.09	2.66	78.62
	Missouri City Coal Co.	12.45	34.48	42.44	10.63	2.95	76.92
39	No. 14, Richmond & Camden Coal Co.	10.20	36.75	41.20	11.85	5.87	77.95
40	Corder Coal Co.	9.90	35.08	43.05	11.97	4.78	78.13
41	Glen Oak, Lexington Coal Co.	14.39	35.00	44.58	6.03	2.01	79.58
42	Valley Mine, Lexington Coal Co.	13.75	35.30	42.40	8.55	2.22	77.70
43	Northwestern Coal Co.	11.00	31.77	45.74	11.49	4.28	77.51
44	No. 2, Higbee	10.84	28.28	49.30	11.58	5.68	77.58
45	Dover Coal Co.	12.33	34.53	42.05	11.09	4.56	76.58
46	Rombauer	12.12	30.10	44.20	13.58	3.52	74.30
47	Carter	11.56	32.93	42.10	13.41	3.50	75.03
42	Graddy, Lexington Coal Co.	12.33	31.55	42.64	13.48	3.94	74.19
49	Grundy Coal Co.	10.07	31.62	43.90	14.41	5.43	75.52
50	J. B. Seitz	10.13	32.23	41.74	15.90	7.56	73.97
51	No. 2, Mendota Coal Co.	17.59	34.11	39.85	8.45	3.21	73.96
52	Mayview Coal Co.	10.50	32.43	40.63	16.44	3.48	73.06
53	Blackbird	13.46	34.88	38.36	13.30	4.29	73.24
54	Lingo	10.16	29.78	41.26	18.80	7.33	71.04

Table III is a summary of tests of various Illinois coals ranked according to the sum of the percentages of fixed carbon and volatile matter.

It seems to be shown in table II that the amount of the fixed carbon and volatile matter puts the various coals, with a few exceptions, in the same order as does the calorific value. Hence it was thought well to arrange the Illinois coals so as to compare them with coals from Missouri according to the amount of fixed carbon and the volatile matter, as the calorific values of Illinois coals were not available. A careful study of tables II and III will show that Missouri coals compare well with those from Illinois.

THE DETERMINED DISTRIBUTION OF COALS IN MISSOURI.

By C. F. Marbut, Professor of Geology.

The accompanying map shows the distribution, so far as known, of the more important coal beds of Missouri. The continuous line along the border of the shaded area indicates that the limit of the coal bed in this direction is determined. Where there is no sharp border to the shaded area it indicates that the coal bed may extend further.

The Bevier coal bed is the thickest and has the widest distribution. Over the area outlined on the map it has an average thickness of nearly four feet. The thickness within the area of any one mine or mining region is essentially uniform, and it is rarely interrupted by faults. "Horses" or "clay rolls" occur occasionally, but not abundantly enough to cause serious interference with mining.

The roof is a sandy shale, sometimes occurring as a sandstone. It is solid enough to furnish a safe roof when properly supported, and in some places it is secure enough for long-wall mining.

The coal bed rests on a layer of underclay with an average thickness of about a foot. This is usually taken up in the roadways, since it is easier to do this than to "brush" down an equal thickness of the shale. The clay rests on a bed of limestone about five feet thick, which gives a solid foundation for the roadway. All through the southern end of this coal field the coal bed consists of two layers of coal, with a one-inch parting of pyritiferous shale. North of Adair county this shale seems to thicken and finally to become thick enough to separate the bed into two independent beds with several feet of shale between them.[1]

The Lexington coal bed is shown on the map to cover a large area along the Missouri river east of Kansas City. It may be said in passing that the unbroken extent of this coal bed over the whole of the area shaded is not proved beyond question. There are mines, however, scattered over this area which operate coal beds of about the same thickness and character as the Lexington bed, and presumably they are the same. It is known to extend southward into Johnson county, but is too thin to be mined profitably under existing conditions. The thickness of the bed within the shaded area varies from sixteen to twenty-six inches. It is overlaid by two feet of black fissile shale,

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(1) For the detailed geology of this coal bed in Randolph and Macon counties, see the Geology of the Huntsville Quadrangle in Vol. XII of the Reports of the Missouri Geological Survey and "The Bevier Sheet" in Vol. IX of the same reports.

III.—TABLE OF PROXIMATE ANALYSES OF ILLINOIS COALS.

Rank.	Shipper.	County.	Name.	Town or District.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Sulphur.	Volatile matter plus Carbon.
‡ 1	New Kentucky Coal Co.		Big Muddy Lump		2.29	37.78	54.53	5.40	.94	92.31
† 2		Jackson		Mt. Carbon	6.1	24.7	66.5	2.7	......	91.2
† 3		Vermillion		Danville	4.8	43.7	45.4	5.2	......	89.1
‡ 4	Glenburn Coal Co.		Mine Run		1.66	46.33	41.32	10.69	3.20	87.65
‡ 5	New Kentucky Coal Co.		Murphysboro		3.71	36.25	50.30	9.74	1.50	86.55
† 6		Jackson		Carbondale	6.4	26.4	59.8	7.4	......	86.2
‡ 7	T. C. Loucks		Lump		3.54	43.44	42.71	10.31	3.89	86.15
† 8		St. Clair		Heintz Bluff.	9.0	37.8	48.2	5.0	3.3	86.0
‡ 9	Du Quoin Union Coal Co.		Du Quoin Lump		3.85	37.39	48.54	10.22	1.86	85.93
‡ 10	New Kentucky Coal Co.		Big Muddy Nut		5.13	36.36	49.44	9.07	1.17	85.80
† 11		Vermillion		Danville	11.0	32.6	53.0	3.6	......	85.6
‡ 12	T. C. Loucks		Pea		3.32	41.68	43.90	11.10	3.87	85.58
† 13		Peoria		Peoria	3.2	36.1	49.2	11.4	......	85.3
† 14		Jackson		Big Muddy	6.4	30.6	54.9	8.3	1.5	85.2
‡ 15	Williamsville Coal Co.		Nut		2.45	43.50	41.69	12.36	4.20	85.19
† 16		Fulton		Cuba	4.2	36.4	48.6	10.8	......	85.0
† 17		Jackson		Big Muddy Odin	7.7	31.9	53.0	7.4	......	84.9
†		Marion		Odin	6.1	34.0	50.9	9.1	......	84.9
‡ 18	Williamsville Coal Co.		Pea		2.65	42.25	42.62	12.48	3.70	84.87
† 19		La Salle		Peru	6.6	37.2	47.2	9.0	......	84.4
‡ 20	Virden Coal Co.		Nut		5.15	40.82	43.54	10.49	3.78	84.36
† 21		La Salle		Streator	7.2	38.9	45.3	8.6	......	84.2
† 22		La Salle.		Streator	12.0	35.3	48.8	3.9	2.4	84.1
†		Perry		Du Quoin	8.9	23.5	60.6	7.0	......	84.1
† 23		Sangamon		Riverton	6.4	35.4	48.4	9.8	......	83.8
† 24		Fulton		Canton	3.5	37.0	46.7	12.8	......	83.7
†		Macon		Niantic	7.9	36.3	47.4	8.5	......	83.7

‡ 25	Gardner Wilmington		Mine Run......		7.90	45.95	37.60	8.55	2.93	83.55
† 26		Vermillion		Danville.....	5.6	37.1	46.4	10.9	......	83.5
† 27		La Salle		La Salle.....	8.2	39.4	44.0	8.4	......	83.4
†		Macoupin		Staunton.....	6.3	57.1	26.3	10.3	......	83.4
‡ 28	T. C. Loucks		Nut............		2.80	42.40	40.46	14.34	3.86	82.86
† 29		Macoupin.		Mt. Olive....	10.4	36.7	46.1	6.8	3.5	82.8
† 30		Sangamon		Loose's.......	10.7	37.6	45.1	6.6	2.4	82.7
† 31		Clinton...		Trenton......	13.3	30.4	52.0	4.3	0.9	82.4
† 32		Christian.		Pana.........	7.2	36.4	46.9	9.5	......	82.3
†		Logan....		Mt. Pulaski..	7.7	35.8	46.5	10.0	......	82.3
‡ 33	Black Diamond Coal Co.		Duff............		1.29	40.80	41.32	16.59	5.10	82.12
† 34		Sangamon		Barclay......	7.4	35.7	46.2	10.7	......	81.9
† 35		Grundy...		Morris.......	7.1	32.1	49.7	11.1	......	81.8
‡	Crerar Clinch & Co.		Pana Pea.......		4.70	41.20	40.60	13.50	3.68	81.8
‡ 36	Steck Coal and Coke Co.		Lump...........		4.30	42.53	39.25	13.92	2.59	81.78
† 37		McClean..		Bloomington.	4.1	36.4	45.2	14.7	......	81.6
‡ 38	T. C. Loucks		Duff............		1.24	39.04	42.21	17.51	4.31	81.25
† 39		Peoria....		Pottstown....	4.6	35.5	45.5	14.4	......	81.0
‡ 40	Riverton Coal Co.		Pea............		3.94	41.10	39.88	15.08	3.96	80.98
† 41		Fulton....		St. David....	2.0	34.6	46.2	17.2	......	80.8
† 42		Macoupin		Girard.......	9.7	34.4	45.8	10.1	3.5	80.2
†		Perry....		Du Quoin....	11.3	30.3	49.9	8.5	0.9	80.2
‡ 43	Wilmington Coal Co.		Washed.........		5.14	39.30	40.88	14.68	3.30	80.18
‡ 44	Crerar Clinch & Co.		Illinois Central.		1.81	36.04	44.12	18.03	3.99	80.16
† 45		Fulton....		Farmington..	3.4	33.9	45.9	16.8	......	79.8
† 46		Logan....		Lincoln......	8.4	35.0	44.5	12.1	......	79.5
†		Marion...		Centralia.....	8.3	34.0	45.5	8.0	......	79.5
† 47		St. Clair.		St. Bernard..	14.4	30.9	48.4	6.4	1.4	79.3
‡ 48	Crerar Clinch & Co.		Du Quoin Pea..		3.15	38.94	39.99	17.92	3.18	78.93
‡ 49	Chicago & K. C. Coal		Duff............		1.15	37.89	41.02	19.94	3.36	78.91
† 50		Fulton....		Dunfermline.	2.5	32.9	45.6	19.1	......	78.5
‡ 51	Colfax Coal & Mining Co.		No. 2, Nut......		2.61	41.36	36.96	19.07	4.19	78.32
† 52		Peoria....		Edwards.....	1.9	34.5	43.6	20.0	......	78.1
† 53		Bureau....		Ladd.........	12.0	32.3	42.5	13.8	......	77.6

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‡ These analyses were made by the Illinois Steel Company at their Chicago plant and were doubtless taken from cars in the coal company's yards, hence the low percentages of moisture.

† These analyses were made by various persons and are published in Kent's Steam Boiler Economy and were doubtless taken from the mines.

III.—TABLE OF PROXIMATE ANALYSES OF ILLINOIS COALS—Continued.

Rank.	Shipper.	County.	Name.	Town or District.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Sulphur.	Volatile matter plus Carbon.
† 54		St. Clair..		Oakland......	8.3	34.4	43.1	14.2	4.4	77.5
† 55		Macoupin		Mt. Olive....	8.1	33.1	44.1	14.7	......	77.2
‡ 56	Girard Coal Co.		Pea.............		.95	36.85	40.24	21.96	3.56	77.09
† 57		St. Clair..		Vulcan.......	10.3	27.9	49.0	12.8	0.7	76.9
† 58		Fulton....		Clair........	3.2	32.9	43.1	20.8	......	76.0
† 59		Macoupin		Gillespie.....	12.6	30.6	45.3	11.5	1.5	75.9
‡ 60	Crerar Clinch Co.		Pana Duff......		4.88	35.59	40.11	19.42	3.58	75.7
† 61		Fulton....		Bryant.......	2.4	32.9	42.6	22.0	......	75.5
† 62		La Salle..		Streator......	9.9	33.2	42.2	14.6	......	75.4
† 63		Bureau....		Ladd........	12.0	32.3	42.5	13.2	......	74.8
† 64		Bureau....		Seatonville...	10.0	33.8	40.9	15.3	......	74.7
† 65		Will......	Wilmington Lump		15.5	32.8	39.9	11.8	......	72.7
‡ 66	Crerar Clinch & Co.		Centralia Duff..		1.50	36.10	36.00	26.40	4.04	72.10
†		Sangamon		Barclay......	10.8	27.3	44.8	17.1	......	72.1
† 67		Madison...		Collinsville...	9.3	29.9	40.8	16.1	3.9	70.7
† 68		Bureau....		Colchester....	11.6	25.0	44.8	18.6	......	69.8
‡ 69	Wenona Coal Co.		Duff............		1.72	33.58	34.74	29.96	4.37	68.32
† 70		Perry.....		St. John.....	13.6	24.5	43.5	15.4	1.8	68.0
† 71		Peoria....		Elmwood.....	1.4	27.7	35.4	35.5	......	63.1

‡ These analyses were made by the Illinois Steel Company at their Chicago plant and were doubtless taken from cars in the coal company's yards, hence the low percentages of moisture.

† These analyses were made by various persons and are published in Kent's Steam Boiler Economy and were doubtless taken from the mines.

and that in turn by six feet of limestone making an excellent roof. It is underlaid by a clay bed, about one foot thick, and this in turn by a bed of limestone about four feet thick.

The character of the roof and underclay and the thickness of the bed make this an ideal coal for long-wall mining.[2]

The Mendota coal bed, when of minable thickness, covers a larger area in Iowa than in Missouri. It is only its southern end that extends into Missouri. Its thickness varies from two and a half to a little more than three feet. It is overlaid by black fissile shale or "slate" about two feet in thickness, and this in turn by about four feet of limestone, thus furnishing a good roof, and by "brushing" down the shale, giving room for good roadways without the necessity of digging much beneath the level of the coal bed. There is no limestone bottom rock to this coal bed.

A coal bed which is thought to be the same as the Mendota coal extends over the greater part of the area of the Bevier coal. It is, however, too thin to be mined on a large scale under existing conditions. In Randolph and Macon counties it is about eighteen inches thick. It is mined for blacksmithing purposes at a few places and is said to be of extra quality.

The *Tebo* coal bed is confined chiefly to Henry county. Its geological relation to the Lexington coal bed is not known. Its average thickness is about two feet and a half. It is overlaid, like the Lexington coal, by two to three feet of shale with a two foot limestone bed overlying the shale. It is underlaid by a few inches of clay and then sandy shales and sandstones extend down to the base of the coal measure series.

The Tebo coal is hard and compact, but it contains rather abundant lenticular masses of pyritiferous shale which must be picked out before the coal is in good condition for the market.

The Jordan coal bed underlies a small area in the vicinity of Deepwater and Brownington, in Henry county. The bed is three and a half to four feet thick, and is underlaid and overlaid by shales. A large part of the area, where this coal bed is thickest, has been worked out.[3]

The Rich Hill coal bed lies in the southwestern part of the state. It is not fully demonstrated that the same coal bed extends over the whole of the area shaded for the Rich Hill coal on the map. It is,

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(2) For the detailed geology and distribution of this coal bed in Ray and Lafayette counties, see the Geology of the Lexington Quadrangle, the Geology of the Richmond Quadrangle in Vol. XII, Reports of the Mo. Geol. Sur., and the Higginsville Sheet in Vol. IX.

(3) For detailed description of the Geology of Henry county, see the Reports on the Geology of the Clinton and Calhoun sheets in the Reports of the Missouri Geological Survey, Vol. XII.

however, known that coal of minable thickness underlies this area, and for that reason it was all shaded alike. The thickness of the bed varies from thirty to forty-eight inches, and locally is a little thicker. It is overlaid by shale and underlaid by shale in some places and by clay in others.[4]

In conclusion, thanks are due to the various mine operators for their kind co-operation, the Wabash; Missouri, Kansas and Texas; Burlington; Missouri Pacific; and Omaha, Kansas City and Eastern railroads for courtesies extended.

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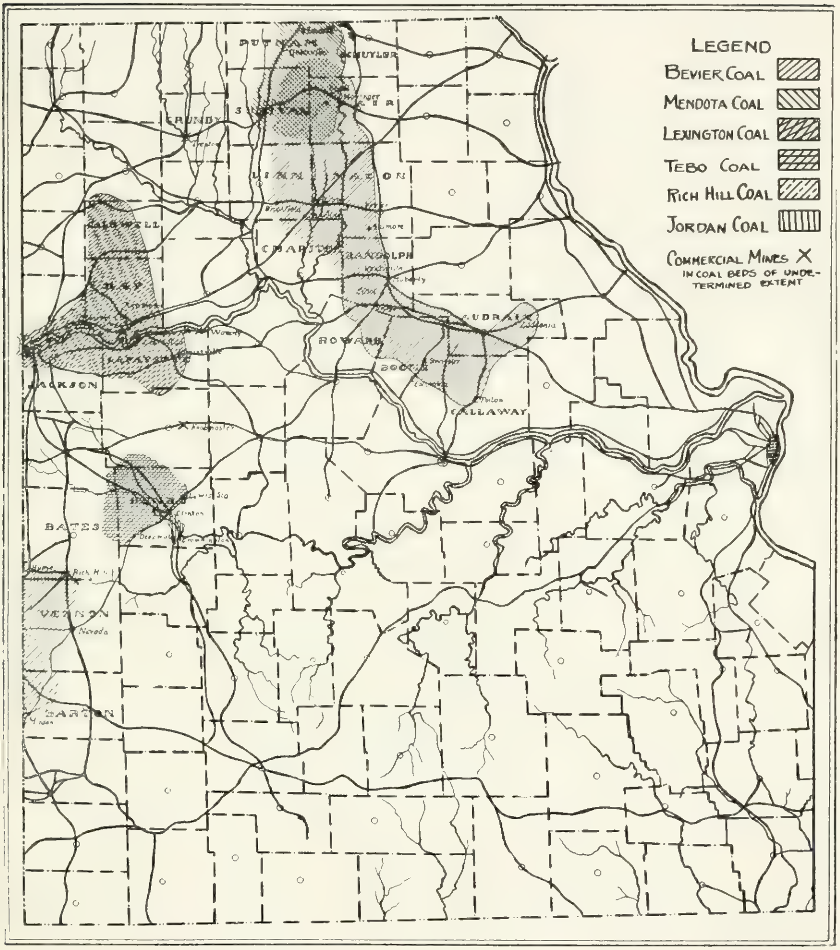
(4) For more detailed descriptions of the coal bed and the mines in this part of the state, consult the Preliminary Report on Coal, Vol. I, Mo. Geol Survey, 1891.

MAP OF MISSOURI, SHOWING THE VARIOUS COAL BEDS.



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FRICTION AND LUBRICATION TESTING APPARATUS

BY

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UNIVERSITY OF MISSOURI
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3000

The Engineering Experiment Station of the University of Missouri was established by order of the Board of Curators July 1, 1909.

The object of the Station is to be of service to the people of the State of Missouri.

First: By investigating such problems in Engineering lines as appear to be of the most direct and immediate benefit and publishing these studies and information in the form of bulletins.

Second: By research of importance to the manufacturing and industrial interests of the State and to Engineers.

The staff of the Station consists at present of a Director and two research assistants together with a number of teachers who have voluntarily undertaken research under the direction of the Station.

Suggestions as to problems to be investigated, and inquiries will be welcomed.

Any resident of the State may on request obtain bulletins as issued or if particularly interested, may be placed on the regular mailing list. Address the Engineering Experiment Station, University of Missouri, Columbia, Missouri.

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PART I.

INTRODUCTION

Unsatisfactory lubrication is a very common trouble and the selection of the very best lubricant, considering both quality and cost, is extremely difficult because of the almost complete absence of definite and precise information upon which to base an intelligent judgment.

It was the realization of this unsatisfactory condition, brought home by the difficulty of choosing between different lubricants for use in the University Power Plant that led the Engineering Experiment Station to attempt to develop apparatus and methods of testing that would yield definite information about the friction and the working characteristics of lubricants under service conditions.

This Bulletin is a preliminary report on the progress of this investigation.

PART II

CHARACTERISTICS OF FRICTION BETWEEN LUBRICATED SURFACES

The *general* characteristics of friction between *well* lubricated surfaces have been pretty well established and only a brief summary will be given here. In the first place it is necessary to point out that it is absolutely essential to have the surfaces thoroughly covered with lubricant. "There are no laws for partially lubricated surfaces."

Rubbing surfaces are lubricated in order to reduce *wear*, *temperature rise* and *energy losses* and the quality of the lubricant should be judged by the extent to which it reduces these effects. As reduction of energy losses usually results also in the reduction of wear and temperature rise the best lubricant would be taken to be the one giving the least energy loss *under service conditions* provided it did not develop some undesirable characteristic such as acidity or drying out rapidly to a gum, etc., when in use.

There are two radically different classes of service to be considered, namely, lubrication of bearings and the lubrication of engine cylinders.

The conditions in bearings are simpler and easier to meet. The temperatures are usually moderate and the direction of motion, the speed and the pressure constant.

For these reasons a number of machines have been built to measure the friction in bearings. [1] Professor Thurston's apparatus in which a split bearing is clamped on the shaft by spring pressure, thus giving an oil film thickness that depends on the constants of the oil as in railroad car bearings and Professor Stribeck's [2] in which a solid-shell ring-oiled bearing having an average oil film thickness that is constant (being determined by the difference in diameter of journal and bearing) a type very generally employed for machines, are particularly deserving of mention.

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[1] Thurston. Friction and Lost Work. John Wiley & Sons.

In engine cylinders the temperatures are high and subject to a wide cyclic variation, the lubricant is also subject to the high and varying pressure of the steam or gas as well as the pressure between the packing rings and cylinder walls; the motion is reciprocating and it is difficult to get the lubricant to the rubbing surfaces and to keep it from being blown on out with the exhaust. In steam cylinders the surfaces are covered with water.

Apparently only one apparatus has ever been built to measure directly the energy loss due to friction in steam cylinders. This apparatus was constructed about the year 1888 by Professor Denton at the Stevens Institute of Technology for the "Lubrication Committee of the Standard Oil Co." It is described in the Transactions of the American Society of Mechanical Engineers, Volume X, page 392, for the year 1889. The measurement in this case was made by having a piston ring free to move in a wide piston slot and fastening the piston ring to spring controlled levers. These levers were all attached to a rod lying in the axis of the cylinder within a hollow piston rod. When the piston moved, friction would make the rings drag and so move the central rod with regard to the piston rod.

Outside the cylinder a registering pencil made a diagram and the distance between the lines on the forward and return stroke was taken as a measure of the drag and friction of the piston ring. The records made in this way consisted of lines about 3-32 inch apart for a well lubricated cylinder with a piston ring pressure of about 70 pounds per square inch. The piston rings in large steam cylinders are usually made to exert a pressure of two or three pounds per square inch and even in the smallest cylinders the pressure is probably never more than fourteen pounds per square inch. The objections that might be urged against this apparatus are: that the value obtained for the friction coefficient depended upon the accurate measurement of the very small distance between two pencil lines; that the piston ring pressure that had to be employed to get even this record was many times the usual piston ring pressures; that the measurement gave the piston ring coefficient alone and there was no difference of steam pressure on the two sides of the ring. Moreover, the construction of the apparatus required a careful elimination of the inertia effects of the rod levers and piston ring by making the center of gravity correspond exactly with the fulcrum of the radial lever connecting the central rod to the piston ring.

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[2] Stribeck. Zeitschrift des Vereines Deutsche Ingenieure V. 45 p 122.

Notwithstanding these objections good work was done with the apparatus and great credit is due Professor Denton for its development.

When smooth surfaces are well lubricated the friction is reduced to that between the particles of the lubricant and depends upon the properties of the lubricant and not upon the material of the surfaces. Some of the lubricant sticks to the moving surface and moves with it; a similar film fastens itself to the other surface and the friction that results is due to the relative motion between the different layers of the lubricant, that is, the friction is determined by the internal resistance of the particles of lubricant to flow. This property of resistance to flow or the internal friction is called "viscosity." It is usually measured by the time required for a given volume to flow through a given sized opening under a given force. A unit of viscosity would be based upon the force required to move one of two parallel surfaces of unit size and distance apart at unit velocity with regard to the other.

The power loss due to friction would then increase with increase of viscosity, of rubbing speed and extent of surfaces, and is independent of the pressure between the surfaces until the pressure becomes high enough to squeeze the lubricant out. The greater the distance between the two surfaces the less will be the relative velocity of the different layers of the lubricant, and consequently the greater the distance between the two surfaces the less the friction will be provided that the lubricant completely fills the space between the surfaces.

In most cases the lubricant is carried from the point where it is supplied and spread over the rubbing surfaces by its tendency to stick to the moving surfaces and so be carried along with them. This tendency to stick and so get where it is needed seems to vary with the viscosity, and to this property the term "body" is applied altho no precise definition or measurement of this property has ever been made.

Lubrication is imperfect and friction high so long as the speed is too low to carry plenty of lubricant to the rubbing surfaces. To keep the surfaces lubricated we must have a lubricant with a higher viscosity (or "body") the lower the speed and the greater the pressure between the surfaces, but so long as the viscosity or body of the lubri, cant is sufficient to keep it between the surfaces the lower the viscosity at the working temperature the better.

The viscosity decreases rapidly with rise of temperature so that the viscosity and friction tests must be made at the working temperature and the temperature must be measured with great care and accuracy.

The proper test for a lubricant is not then merely a viscosity measurement but a test for the friction under service conditions of temperature, speed, pressure and clearance.

When tested in this way it will be found that the lubricant that gives the best results is one with a higher absolute viscosity, the higher the temperature and the pressure and the lower the speed. Moreover by a proper choice of lubricant the friction coefficient may be brought to a minimum value and this minimum value is *practically the same* for all lubricants. In other words, for every lubricant (free from foreign and harmful ingredients) there is a set of working conditions under which it will give this minimum friction coefficient. This minimum friction coefficient lies between the values of ½ of one per cent and one per cent.

The apparatus for testing lubricants must therefore permit of the reproduction of any set of service conditions and, more important still, must make it possible to keep these conditions absolutely constant during the test or comparison.

These conditions are:

Adequate supply of lubricant.
Definite and constant values for the rubbing speed.
Definite and constant pressure.
Definite and constant temperature.
Definite and constant thickness of lubricating film (or clearance between the rubbing surface.

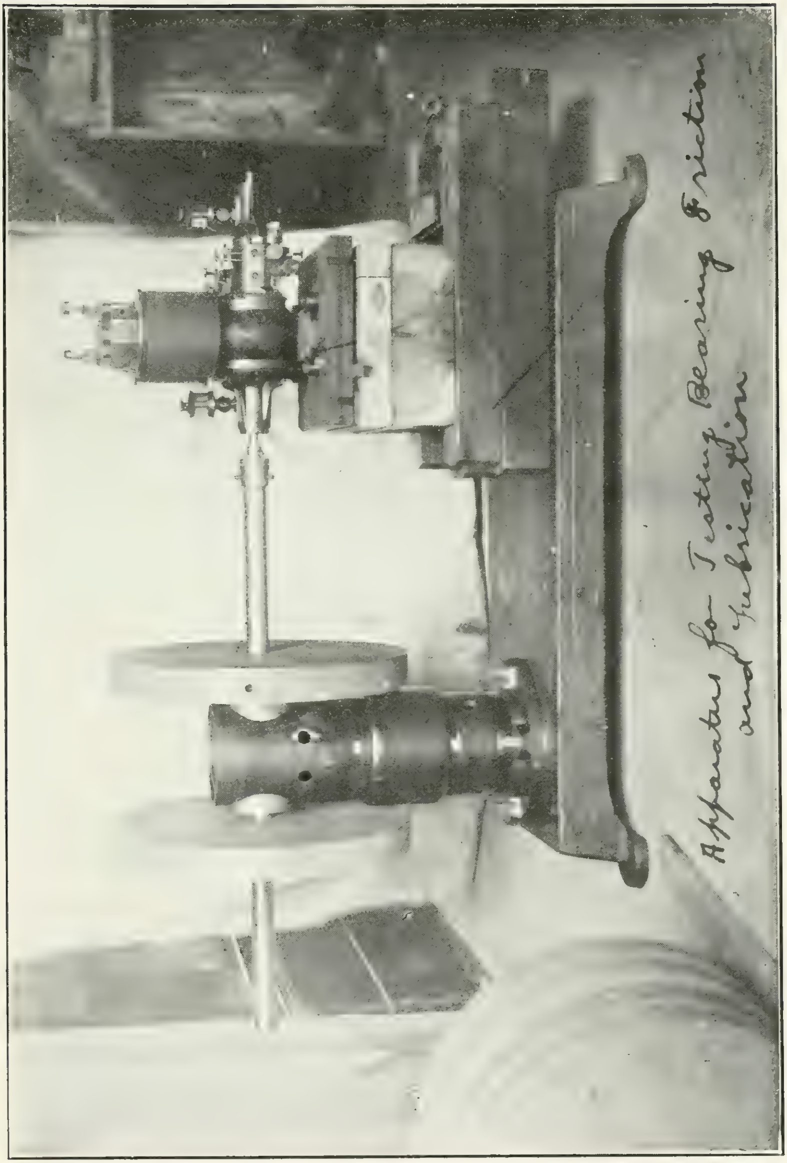
PART III

DESCRIPTION OF APPARATUS.

a. Apparatus for Testing Bearing Friction and Lubrication.

The accompanying photograph and sketch give an idea of the general appearance of the apparatus. The principle adopted was that of measuring electrically the input to a motor driving a shaft that is supported by a single bearing and carries discs to produce the desired pressure on the bearing. The motor losses may be subtracted and so the net power used by the friction of the test bearing obtained. The speed is controlled by the voltage applied to the motor. The temperature is controlled by a water jacket and measured by a thermometer in a pocket close to the bearing surface. The pressure between the shaft and the bearing is determined by the number of discs put on the shaft. The clearance or play of the shaft in the bearing is determined by measuring the diameter of the shaft and the bore of the bearing.

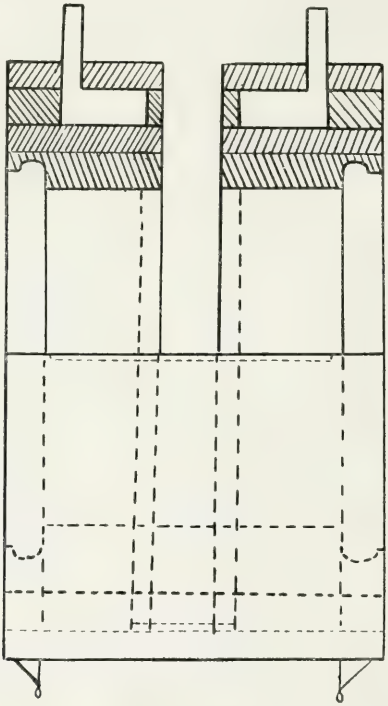
The bearing in this apparatus is 2¼ inches in diameter and two inches long. The oil is carried from the reservoir by the usual type



Apparatus for Testing Bearing Friction and Lubrication of oil ring or rings to the top of the bearing and the amount of oil supplied measured by timing the drops from little drain pipes leading off from channels at each end of the bearing. The motor can be run at any speed up to 1200 revolutions per minute corresponding to rubbing velocities up to 708 feet per minute (215.8 cm. per second.)

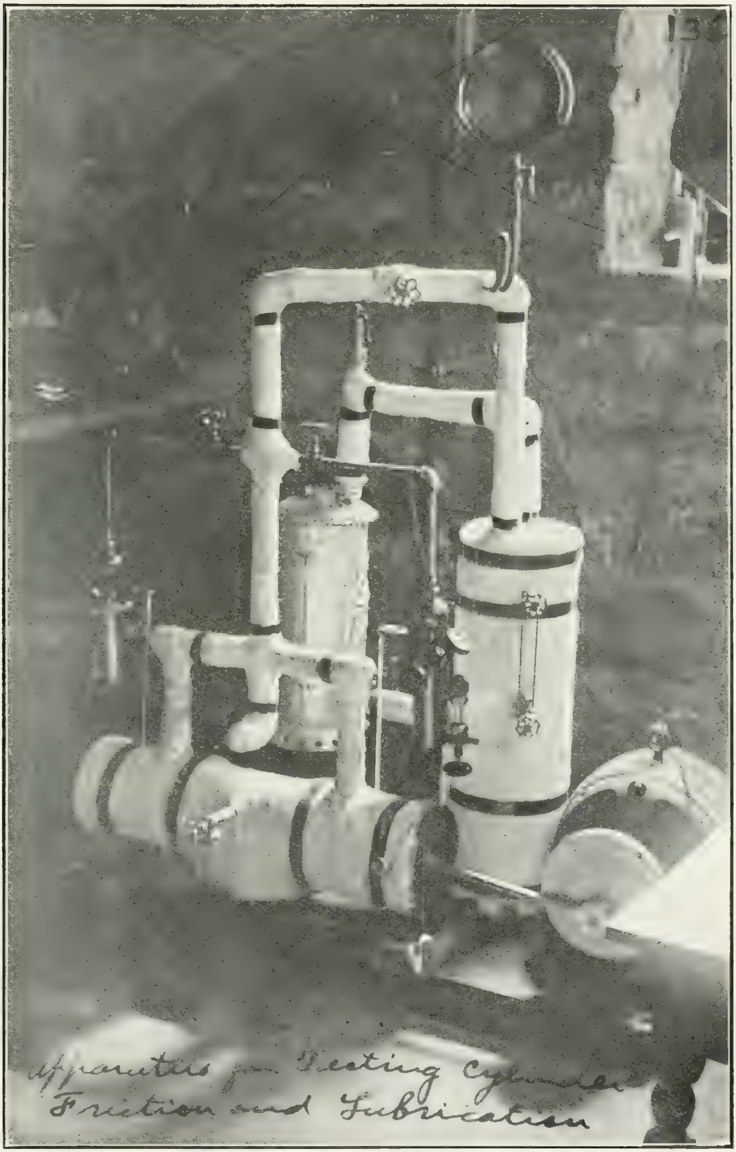
b. Apparatus for Testing Steam Cylinder Friction and Lubrication.

The method of measurement adopted here was, as in the previous case, to measure electrically the input to a motor and to subtract the motor losses. In this case the motor was provided with a crank disc



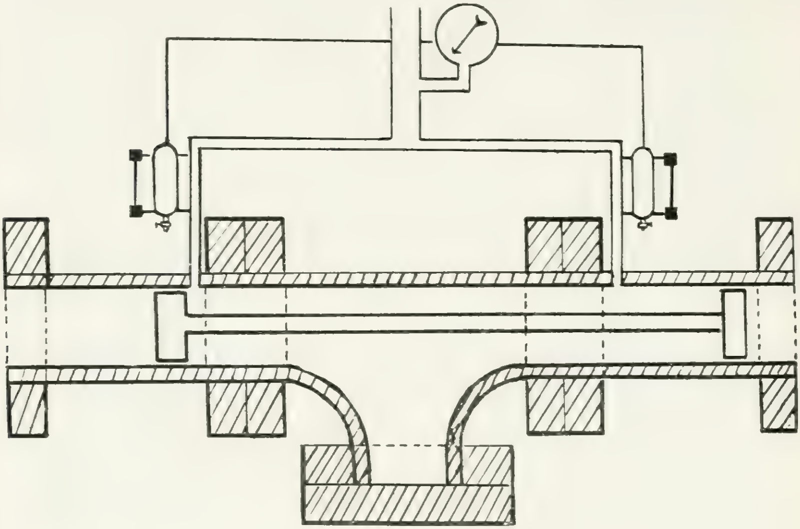
TEST BEARING

and connecting rod driving two pistons fastened on the opposite ends of a piston rod with a steam space and a pocket for collecting condensation between the two pistons. The construction is shown in the accompanying sketch and photograph, the latter showing also the gas heated, coiled tube boiler and the water tank, as well as the two



Apparatus for Testing Cylinder Friction and Lubrication

Detroit one pint lubricators connected to steam pipes entering the cylinder near the ends, just inside of the inner positions of the pistons. The use of two pistons of the same size with a steam space between them prevents the steam from doing any work itself or having work done on it. Each end of the connecting rod is fitted with Hess Bright ball bearings so that its friction is negligible compared with that of the pistons. Thermometers in pockets are provided nearly opposite the mid stroke positions and within 1-16 inch of the inner wall of the cylinder and give an indication of the temperature of the rubbing surfaces. An Ashcroft standard test gage is used for measuring the steam pressure



TEST CYLINDER

The cylinder bore is 3 inches (7.62 cm.) and the stroke was 3 inches (7.62 cm) when the apparatus was first set up, being changed later to 5 inches (12.70 cm.) There are three, standard type, cast iron, piston rings on each piston. Each ring has a face width of .2175 inches (.553 cm.) These rings gave a pressure of about 3.23 pounds per inch of circumference and 14.92 pounds per square inch (.577 kg. per cm. and 1.050 kg. per sq. cm.) after being worn to a fit.

As the cylinder ends are open only one face of the piston is subjected to steam pressure and temperature, the other face being subject to conditions corresponding to those of the exhaust of a non-condensing engine. The oil fed to the steam pipes entering the cylinder near the position occupied by the pistons at the inner end of their strokes is carried to the rubbing surfaces by the steam as in the steam engine.

Both pieces of apparatus are in their development period and it is expected that improvements will be made and the range of conditions extended as additional experience is gained. Some of the changes and improvements already contemplated are:

An additional bearing for the bearing testing apparatus, split in order to make tests with a clearance distance that will be absolutely unaffected by wear.

A larger cylinder bore for the cylinder friction testing apparatus.

A set of spiral-spring-controlled piston rings allowing adjustment for different piston ring pressures.

PART IV

RESULTS OF TESTS

A test apparatus to be of any real value must first of all give reproducible results and the test figures quoted here are intended principally to show what may be expected in this respect.

The following values were obtained with the first apparatus set up for testing bearing friction. The bearing in this case was a standard motor bearing, solid babbitted shell 4 inches long, 1¼ inches bore, having two oil ring slots and four oil rings, *two rings in each slot*. The bearing had a projected area of 3.9 square inches, a load of 176 pounds and a pressure of 45.2 pounds per square inch.

Bearing Friction Test Results

Date	Bearing temp. degs. centigrade	Speed		Current in Amperes			Power Consumption of Bearing Watts	Friction coefficient
		R.P.M	Feet per Minute	Total	Motor losses	Net		
8-18-1910	35.0	700	232.5	2.20	.57	1.63	22.85	.02475
8-22-1910	35.1	700	232.5	2.27	.57	1.70	23.93	.02594
8-23-1910	35.6	693	230.7	2.26	.57	1.69	23.40	.02564
8-24-1910	35.8	693	230.7	2.20	.57	1.63	22.50	.02470

One interesting and altogether unexpected peculiarity of bearing lubrication was discovered during the preliminary trial tests on this bearing, and later confirmed by tests on the 2¼ inch bearing.

This was that with the single oil ring in each slot *supplied by the manufacturer* the oil supply was insufficient and the friction high and variable, the range being from a well defined minimum to a value twice as large. This difficulty was completely eliminated by the use of *two* rings in each slot, the two nearly but not quite filling the slot.

The cylinder friction apparatus test results quoted in the table below, as well as those plotted in the accompanying curve sheet were taken just after the apparatus had been set up and while the surfaces were still only partially worn smooth. They are given principally to illustrate the reproducibility of results.

Cylinder Friction Test Results; 3″ Cylinder, 3″ Stroke.

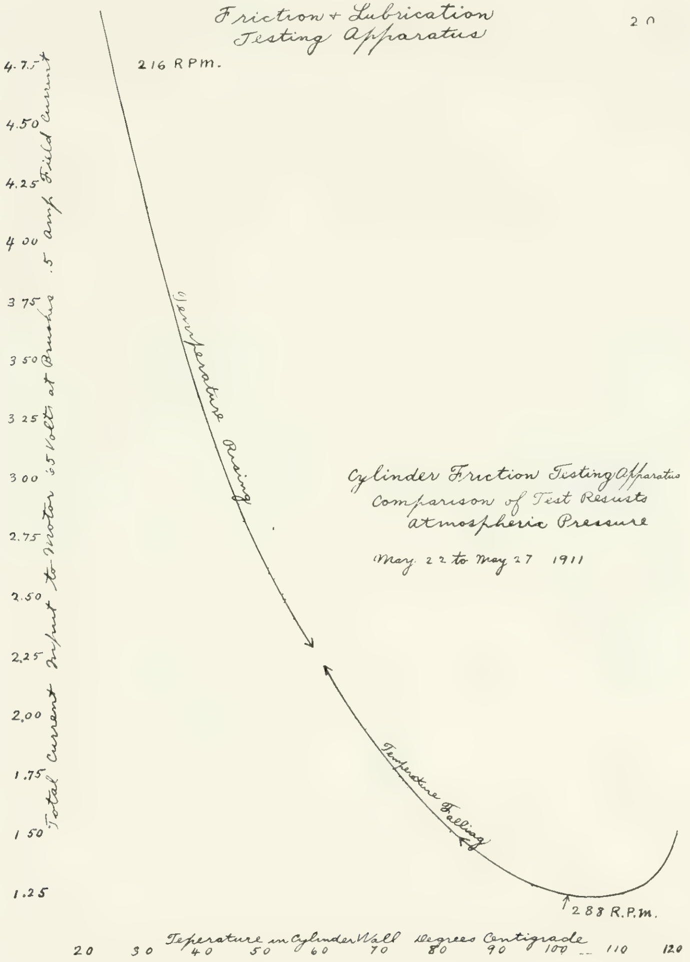
Date and Time	Gage pressure pounds per square inch	Temp in cylinder wall degrees Centigrade	Oil Feed, Seconds per Drop	Speed		Current in Amperes			Friction coefficient
				R.P.M.	Feet per Minute	Total	Motor Loss	Net	
	Cylinder Filled With Steam at Atmosphere Pressure								
Apr. 3, '11 9:35 p. m.	0	94.4	67.3	277	217.5	1.23	.266	.964	.02728
11:14 p.m.	0	95.6	26.2	275	216.0	1.26	.266	.994	.02810
Apr, 4, '11 12:15 a.m.	0	94.0	72.7	274.5	215.5	1.26	.265	.995	.02815
Apr. 5, '11 9:10 a. m.	0	94.0	62.0	274.0	215.	1.27	.265	1.005	.0284
9:35 a. m.	0	94.	73.2	274	214.5	1.27	.265	1.005	.0284
	Cylinder Filled with Steam Under Pressure								
Apr. 3. '11 10:45 p.m.	19	119.3	24.4	253	198.8	1.72	.257	1.463	.0414
10:50 p.m.	21.5	120.6	24.4	255	200.5	1.68	.257	1.42	.0402
Apr. 5, '11 10:30 p.m.	20	120.5	45.0	249	195.4	1.80	.256	1.54	.0436

The increase of friction in the cylinder when the outlet is closed and the steam pressure raised has been confirmed by a number of subsequent tests. There are several influences at work.

1. The flow of steam carries the oil to the rubbing surfaces tending to reduce the friction.

2. The leakage of steam past the piston rings carries the oil away so that the friction tends to increase unless the oil supply is greatly increased.

3. The steam also leaks into the space back of the piston rings causing them to press against the cylinder wall more firmly and so tending to increase the friction.



Cylinder Friction Testing Apparatus
Comparison of Test Resusts
atmospheric Pressure

May 22 to May 27 1911

4. The decreased viscosity at high temperatures allows the oil to be squeezed out, tending to increase the friction unless the speed be raised or the piston ring pressure lowered.

The effect of the first factor was detected by suddenly applying air pressure to the inner faces of the pistons. At once the friction decreased slightly as the air forced more oil along with it to the rubbing surfaces. This effect is, however, very small, the change in one case being from 2.08 amperes supplied to the motor with zero gage pressure to 2.02 amperes when the air pressure was suddenly raised to 20 pounds per square inch gage pressure. (Test April 20, 1911).

The effect of leaking steam in carrying away oil and increasing the friction is very marked. The current required to drive the machine decreasing from 3.77 amp. with an oil feed of 37.0 seconds per drop to 2.58 amp when the oil feed was increased to 9.4 seconds per drop. Furthur increase of oil feed did not decrease the friction, the current required for a rate of oil feed of 3.4 seconds per drop being 2.57 amp. (Test June 8, 1911.)

The effect of steam pressure in the piston ring slots was detected by arranging drains so that the backs of the piston rings could either be subjected to full steam pressure or to atmospheric pressure. With full pressure on the backs of the rings the friction with increasing steam pressure rose more rapidly than before while with the piston ring slots open to the atmosphere the friction actually decreased with increasing steam pressure. (Tests of May 26 and May 27, 1911.)

The effect of temperature in lowering the viscosity to a point where it may be squeezed out unless the speed is raised or the pressure between the rubbing surfaces lowered is a well known characteristic of oils. That this effect is a factor in the increased friction is shown by the part of the curve above 107° on the curve already shown, which was taken with constant atmospheric pressure. (Test of May 27, 1911.)

This was further checked by making runs with decreased piston ring pressure in which the temperature for minimum friction was much higher (about 137° C for half normal piston ring pressure. Test June 5. 1911) and by runs at a higher speed which also gave a high temperature for minimum friction (about 142° C, for a little over double speed. Test June 8, 1911.)

PART V

CONCLUSIONS

The tests so far made with the preliminary apparatus lead to the following conclusions:

1. A fair degree of reproducibility and a moderate amount of experimental error has already been obtained.

2. A single oil ring per slot in an oil ring bearing may not supply sufficient lubricant.

3. The friction in steam cylinders may under some conditions increase with increase of steam pressure.

4. The principal causes so far found for the increase of steam cylinder friction with increase of steam pressure are:

   a. Leakage past the piston rings carrying away lubricant and requiring an increased oil supply.

   b. Presence of steam pressure on the backs of the piston rings thru leakage.

   c. Decreased viscosity at high temperatures allowing the piston rings to squeeze the lubricant out.

It is a pleasure to acknowledge here the help given by members of the faculty of the University of Missouri and by the discussion at the annual convention of the Missouri, Gas Electric Light, Street Railway and Water Works Association.

It is expected that additional test results will be obtained and that they will be incorporated in a separate Bulletin.

PART VI

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THE UNIVERSITY OF MISSOURI BULLETIN

ENGINEERING EXPERIMENT STATION SERIES
VOLUME 2. NUMBER 3.

AN INVESTIGATION OF THE ROAD MAKING PROPERTIES OF MISSOURI STONE AND GRAVEL

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AND
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MDCCCXXXIX

UNIVERSITY OF MISSOURI
COLUMBIA, MISSOURI.
September, 1911

The Engineering Experiment Station of the University of Missouri was established by order of the Board of Curators July, 1, 1909.

The object of the Station is to be of service to the people of the State of Missouri.

First: By investigating such problems in Engineering lines as appear to be of the most direct and immediate benefit and publishing these studies and information in the form of bulletins.

Second: By research of importance to the manufacturing and industrial interests of the State and to Engineers.

The staff of the Station consists at present of a Director and two research assistants together with a number of teachers who have voluntarily undertaken research under the direction of the Station.

Suggestions as to problems to be investigated, and inquiries will be welcomed.

Any resident of the State may on request obtain bulletins as issued or if particularly interested, may be placed on the regular mailing list. Address the Engineering Experiment Station, University of Missouri, Columbia, Missouri.

INTRODUCTION.

Realizing the popular interest that has been awakened for good roads in Missouri and elsewhere in recent years and that the majority of the permanent roads must have for their wearing surface suitable rock or gravel that can be obtained at a reasonable cost, The Engineering Experiment Station of the University of Missouri undertook the investigation of the road making properties of Missouri stone and gravel in the fall of 1910. In this investigation the Station has had the cooperation of Mr. Curtis Hill, State Highway Engineer, who has rendered very valuable assistance in securing the testing apparatus and in collecting the materials for testing.

On November 22, 1910, Messrs. L. P. Scott, G. C. Broadhead, and R. A. See, all graduates of the Civil Engineering Department of the University of Missouri, were sent out to collect samples of stone and gravel that might be used in road building. Each of these men was instructed to cover a certain part of the state, confer with the County Highway Engineers, other county officials and prominent men interested in good roads; and collect samples from as many quarries and gravel banks as possible in the time allotted for this work. The time allowed for making this collection was limited as this work had to be completed before Jan. 1, 1911; therefore a few counties which have abundant road material had to be omitted, other counties were not visited as it was known that they had very little or no road material of this character.

The wearing surface of a macadam or gravel road, often called the road metal, must possess certain physical properties in order to be a good road material. These properties are hardness and toughness to resist the wear of the traffic, and cementing properties to bind the stones together and produce a smooth hard surface. These qualities are often found in the same stone but sometimes a combination of two materials are required to produce the best results, one for hardness and toughness and the other for a binding material. The laboratory tests have been arranged to bring out the comparative values of these desirable physical properties. The testing machines and the methods of testing are the same as those used by the Office of Public Roads of the U. S. Department of Agriculture; so the result can be compared directly with those published by the Office of Public Roads at Washington D. C. A few of these tests have been made by senior students in Civil Engineering under the supervision of the director of the road laboratory, but nearly all of them have been made by Mr. R. Warren Roberts, personally, in connection with his thesis for the degree of Civil Engineer.

Most highway engineers and road builders will agree that the best test of a road material is its action under the traffic it is required to carry, but this test is an expensive one and requires a year or more to carry it out; therefore the purpose of these laboratory tests is to enable the highway engineer to ascertain in advance if a stone is satisfactory for road building purposes, or if there are several kinds of material available, which is the best or what combination of available materials is likely to give the best results.

It is the hope of the authors of this bulletin that the results of these tests will prove to be a valuable aid to the highway engineers of the state in selecting the material for building the permanent roads of the state.

The methods used in making the tests will be described in detail and then the counties from which samples have been obtained will be taken up in alphabetical order. Each sample (numbered in the order in which the tests were made) will be described, its location definitely given and the results given from the tests for the French Coefficient of wear, for cementing value, for hardness, and for the resistance to impact or toughness, as these four tests indicate the physical properties which determine the value of a material for road building purposes.

The results of these tests, together with the specific gravity, weight per cubic foot, and water absorbed per cubic foot will be shown in tabular form so that comparisons can be readily made.

A part of each sample has been placed in a glass jar, properly labeled, and kept in the laboratory as an exhibit.

It was at first contemplated to publish a map of the state in this bulletin, on which the location of each sample tested would be shown by its number, but it was decided later to omit this map as it would be too bulky if made large enough to be satisfactory. If any one wishes such a map for comprehensive study of these results, it can easily be prepared by taking any good map of the state, such as the State Railroad Commissioners' Map, and placing the number of each sample in its proper place from the description of the locality from which it was obtained.

DESCRIPTION OF METHODS AND APPARATUS FOR TESTING ROAD MATERIALS.

ABRASION MACHINE.

(Deval Type.)

This machine (Fig. 1) consists essentially of the pully "A", driving the shaft " B B," upon which are mounted the two cast iron cylinders "C C" in such a way that the axis of the cylinders are inclined at an angle of 30 degrees with the axis of rotation. The cylinders are 20 cm. in diameter and 34 cm. in depth inside. The shaft is set in two bearings "D D" and carries at "E," a revolution counter. The method of fastening the cylinders to the turning frame is shown at "F."

ABRASION TEST.

Five killograms (11 lbs.) of rock, broken in pieces as nearly uniform in size as possible and as nearly 50 pieces as possible constitute a test sample. The pieces must pass a 2½ inch ring and be retained on a 1 inch ring. The total weight of rock in a test is within 10 grams of 5 killograms. All test pieces are washed free from all detritus and thoroughly dried in an oven before weighing. Three hours at a temperature of 150 degrees centigrade is ample length of time for thorough drying.

The test sample is now weighed and placed in the machine. Ten thousand revolutions, at the rate of between 30 and 33 revolutions to the minute, constitute a test. After the test the sample is washed free from all detritus and dried again. Only the percentage of material worn off which will pass through a 0.16 cm (1-16 inch) mesh sieve is considered in determining the amount of wear. The amount of wear is expressed either in the per cent of the 5 killograms used in the test, or the French coefficient, which is in more general use, is given. That is, the coefficient of wear equals $20 \times \frac{20}{w}$ equals $\frac{400}{w}$ equals $\frac{40}{\text{per cent of wear.}}$ "W" being the weight in grams of the detritus under 0.16 cm. ($\frac{1}{16}$ inch) in size per killogram of rock used.

In interpreting results of this test a coefficient of wear below 8 is considered low, between 8 and 13 medium, between 13 and 20 high, and over 20 very high.

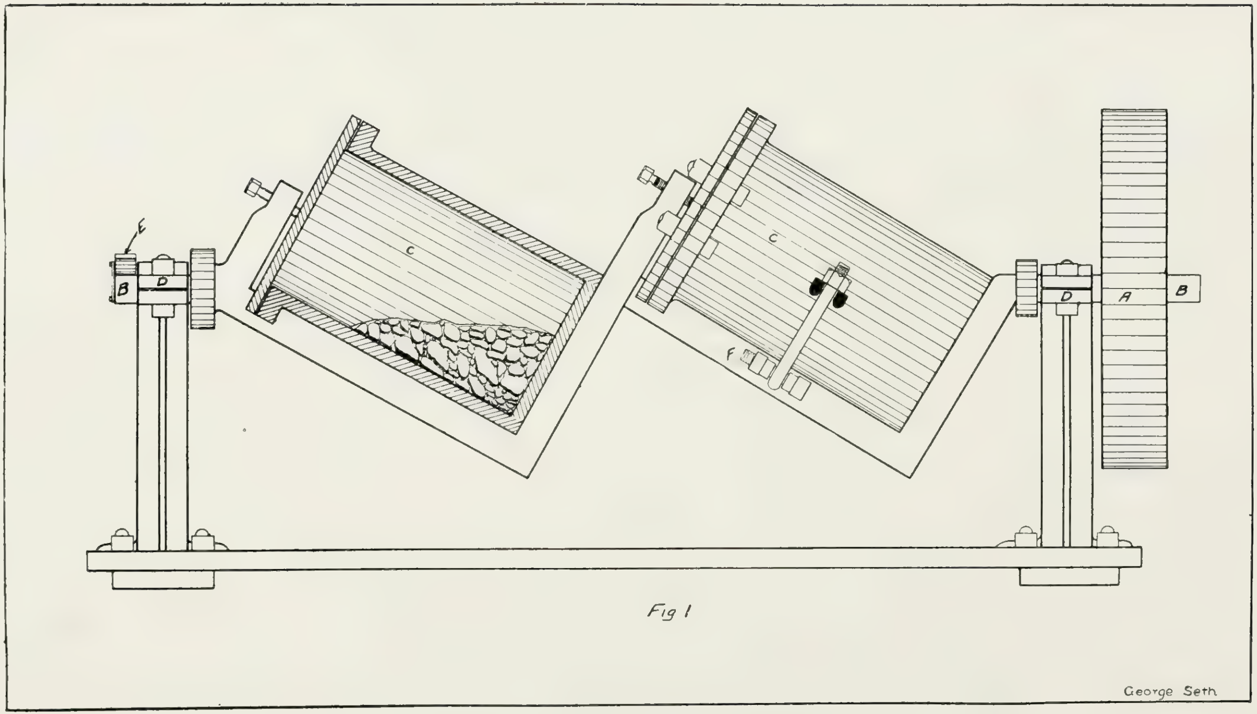
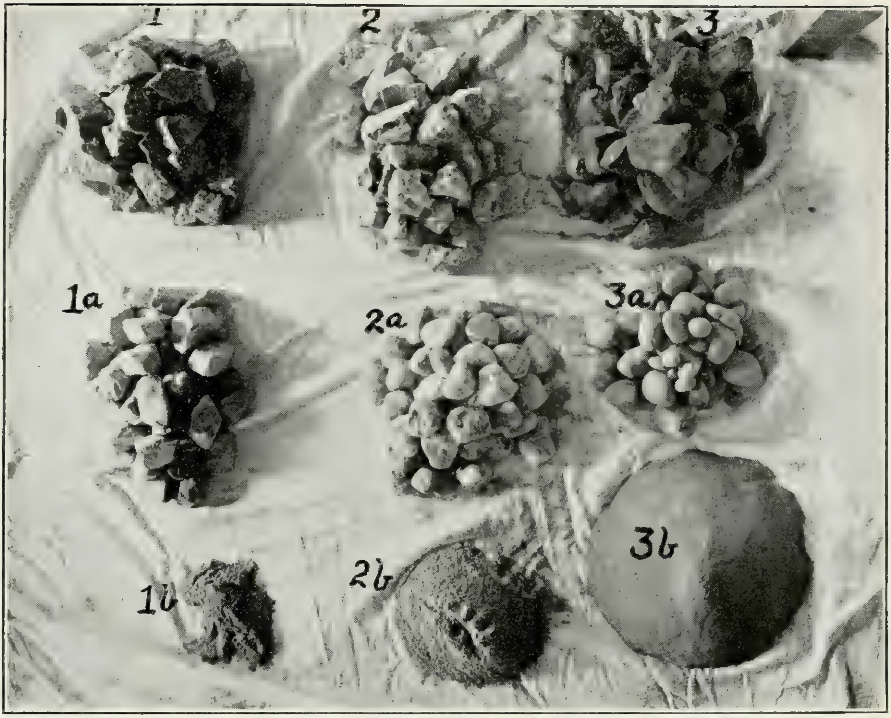


Fig 1

Abrasion Machine. (Deval Type.)



(Fig. 13.)

Samples of Granite, Limestone, and Sandstone Before and After the Abrasion Test.

No. 1	Granite retained on a 1 in. screen.
No. 1a	Granite retained on a 1-16 in. screen.
No. 1b	Granite passing a 1-16 in. screen.
No. 2	Limestone.
No. 3	Sandstone.

CEMENTATION TEST.

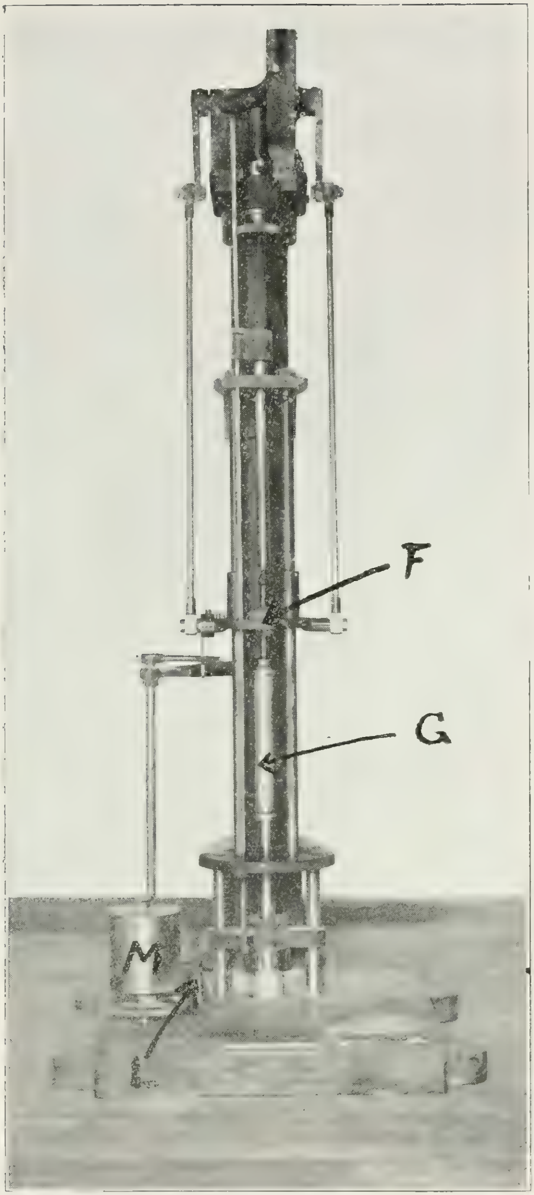
One half killogram of the rock to be tested is broken sufficiently small to pass a one half inch mesh. This material is placed in a ball mill (Fig. 3) together with about 90 cubic centimeters of water sufficient to produce a stiff paste after grinding. At the end of 5,000 revolutions, the material is taken from the mill and about 28 grams of the dough is placed in a cylindrical metal die 25 mm. in diameter. A closely fitting plug (see fig. 4) supported by guide rods is inserted over the material which is then subjected to a pressure of 132 killograms per square centimeter. The die is placed on an iron platform supported by a piston rod which is connected directly with an hydraulic piston below. Water under pressure is admitted to the hydraulic cylinder through a small orifice in the pipe. As the piston rises, the platform and die are carried up with it, the plug of the latter coming in contact with a yoke attached to a properly weighed lever arm. The height of the briquet is measured and if it is not exactly 25 mm. (.98 inch) in height, the requisite amount of material is added or subtracted to make the next briquet the required height. Five briquets are made from each test sample and allowed to dry 20 hours in the air and 4 hours in a water bath at 100 C. After cooling 20 minutes in a dessicator, they are tested by impact in a machine especially designed for that purpose.

This machine (fig. 6) consists of a 1 kilogram hammer which falls on a flat end plunger of ½ kilogram weight, which is pressed upon the briquet by two light spiral springs surrounding the guide rods. The standard fall of the hammer is 1 centimeter and this blow is repeated until the bond of cementation of the material is destroyed. The number of blows required to destroy the bond of cementation as described above is noted and an average obtained from the five briquets as a cementing value.

In interpreting results of this test, values below 10 are called low; from 10 to 25, fair; from 25 to 75, good; from 75 to 100, very good; and above 100, excellent.

THE PAGE IMPACT MACHINE FOR TESTING CEMENTING VALUE OF ROCKS.

The hammer "G" is raised by means of the grip "F". The rise of the grip is such as to give an effective drop of 1 cm. to the hammer. The reaction of the briquette after each blow of the hammer produces a vertical movement in the end of the lever "L". This motion is recorded on a sheet of silicated paper wrapped around the recording drum "M" by means of a brass point at the end of the lever "L". The number of blows necessary to destroy the bond of the briquette is taken to be the cementing value of the material.



(Fig. 6.)

The Page Impact Machine for Testing Cementing Value of Rocks.

BALL MILL.

For Grinding Rock Samples.

The circular cast mill "A B", consisting of the two unequal segments "A" and "B", revolves in a vertical plane about the shaft "C C", which bears in the pillow blocks "D D", and is driven from the pulley "E".

Five hundred grams of coarsely crushed rock sample and about 90 cubic centimeters of water are placed, together with the steel shot 13 cm. in diameter, in the mill; the segments bolted together at F and the sample ground for 2½ hours in the mill revolving at the rate of 2,000 revolutions per hour. The grinding action of the steel shot reduces the rock sample to a stiff dough, in which condition it is ready to be moulded into biquets.

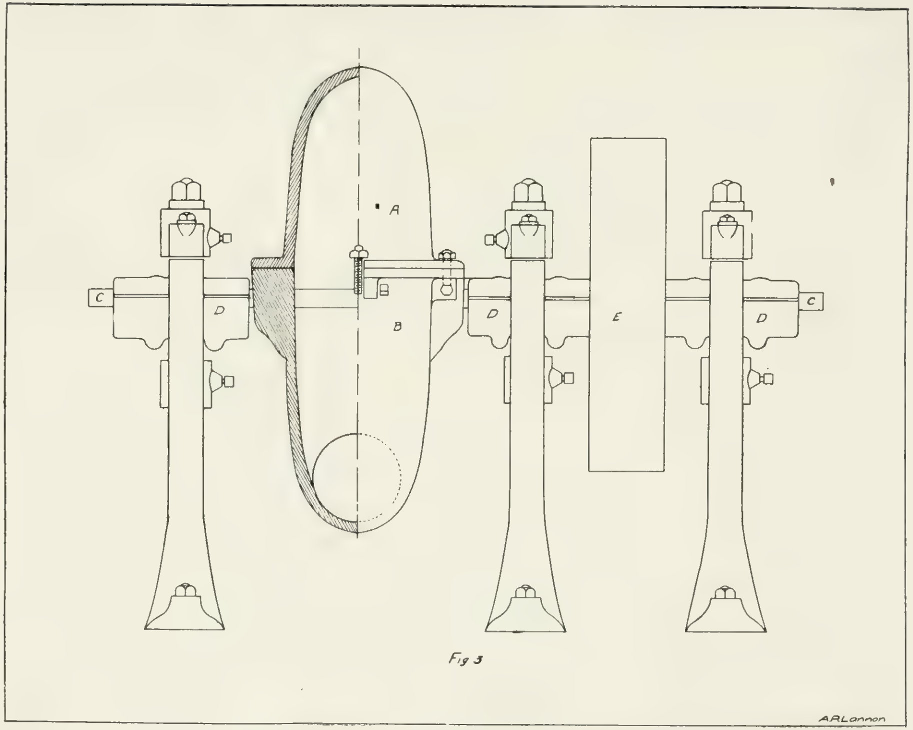


Fig 3

Ball Mill (For grinding rock samples.)

BRIQUETTE MACHINE.

For Molding Rock Dust Specimens

The hydraulic cylinder "A" (Fig. 4) supports an iron platform "B" through the piston-rod "C", the cylindrical metal die "D", provided with a closely fitting plug "E" supported by the guide rod "K" and containing the material to be compressed, is placed upon the platform and water admitted to the cylinder through the supply pipe "L". As the piston rises, the platform and die are carried up with it, the plug of the latter coming in contact with a properly weighted lever arm "G". The weight "H" is adjusted on the lever arm, so as to give a maximum pressure of 132 kilograms per square centimeter on the compressed material, which pressure is applied only for an instant. The electrical attachment shown is not in use at present, as it has been found more satisfactory to operate the water by hand.

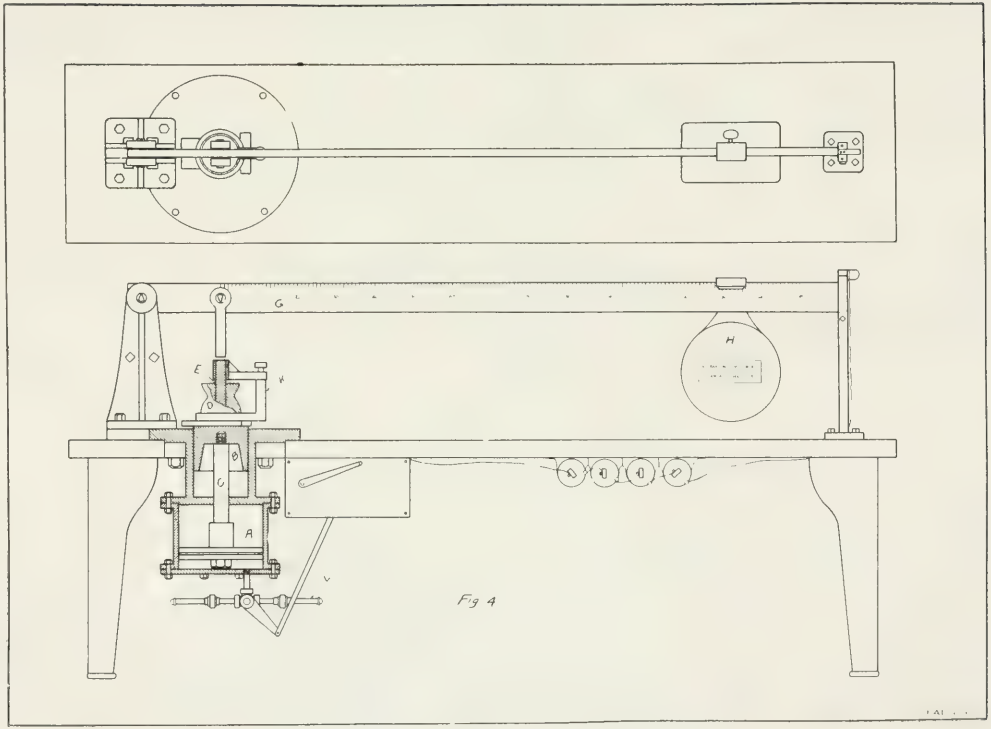


Fig 4

Briquette Machine. For molding rock dust samples.

CORE DRILL.

For Preparing Rock Cores.

This machine (Fig. 7) consists essentially of a drill press in which may be placed a core drill.

The steel core tube "A" carries at its lower end the brass ring "B" containing four black diamond points, spaced as shown, to cut a rock core (see Fig. 8) 25 mm. (.98 inch) in diameter, the core tube is connected at the upper end with the brass casing "C" through which passes the lower part of the sank "D".

The water supply tube "F" is connected directly to the stationary brass ring "G" which has a semi-circular section cut on its inner side to fit a similar section in the casing "C" forming a circular hollow tube, one-half of which is stationary and the other half movable with the drill. Four small holes "I" forming the vertical tube "J", connect the ring with the inside of the core tube "A", the whole forming an arrangement for carrying water from supply tube "F" to the inside of the revolving drill, thereby flushing out the cuttings.

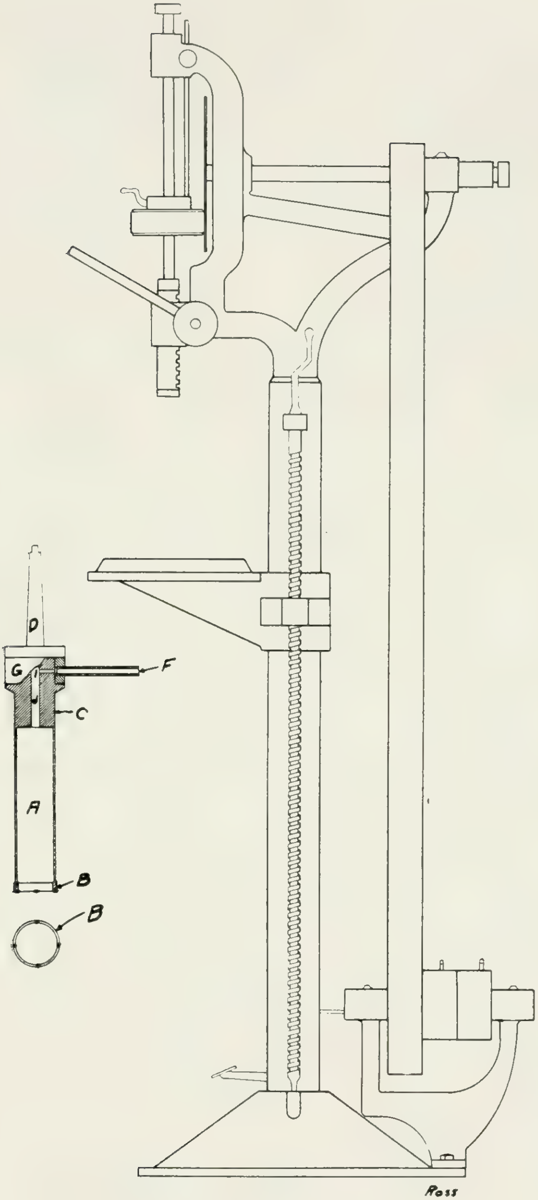
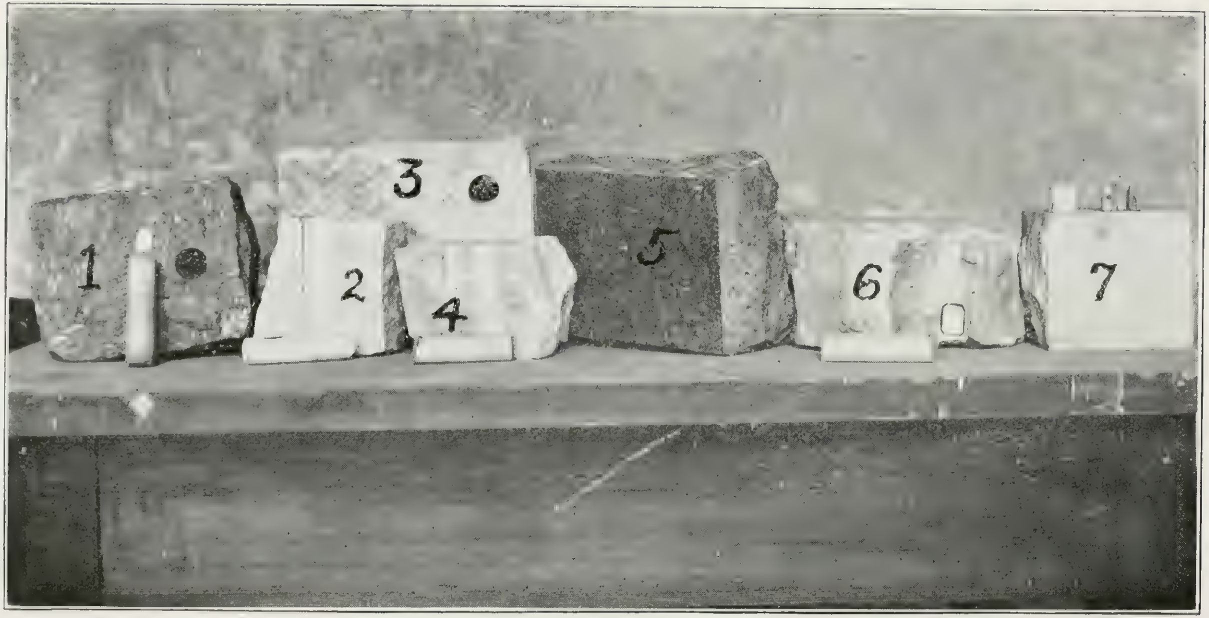


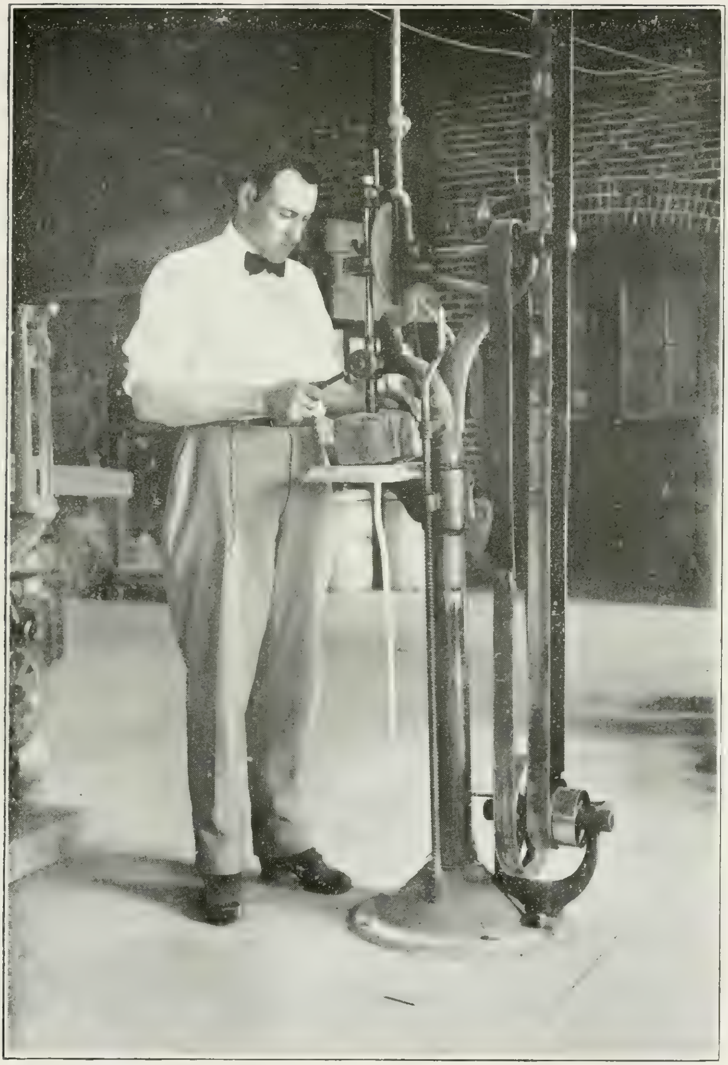
Fig 7
Core Drill. (For preparing rock cores)



(Fig. 8)

Samples of Rock From Which Cores Were Cut.

No. 1. Red Granite
No. 2. Dolomite
No. 3. White Sandstone
No. 4. White Limestone
No. 5. Red Granite
No. 6. Mineral Bearing Limestone
No. 7. Marble



(Fig. 10)

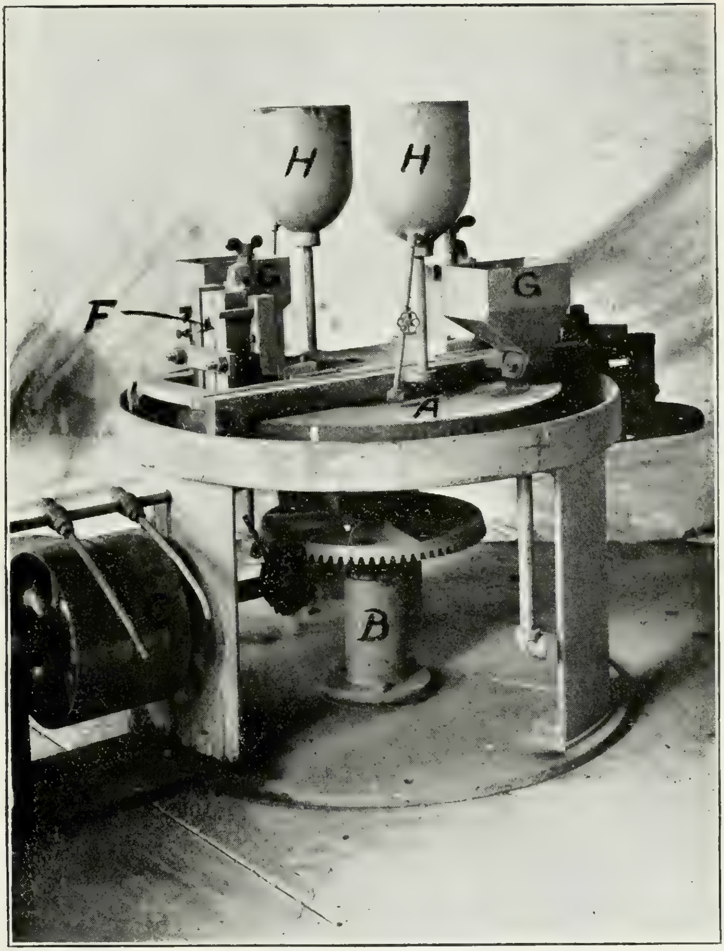
Cutting the Cores for the Hardness and Toughness Tests.

HARDNESS MACHINE.

Dorry Type

The circular cast steel disk "A" revolves in a horizontal plane about the vertical shaft "B" which is driven from the pulley "C" by means of the bevel gear "D". The cylindrical rock core 25 mm. in diameter is clamped in the clip "F" and held in position over the revolving disk, so that the lower end of the test specimen rests against the disk with a pressure of 1250 grams. Sand, between 30 and 40 mesh, obtained by screening crushed quartzite, is fed continuously upon the disk through the funnel "G". Water is also fed upon the disk through the funnel "H".

This machine is equipped for making six tests at a time, the specimens being held on opposite sides of the grinding disk at a distance of 26 cm. from the center.



(Fig. 11)

Hardness Machine.

(Dorry Type)

TEST FOR HARDNESS.

A cylindrical core 25 mm. in diameter and 25 mm. high is cut from a specimen of the rock with a diamond core drill (see Fig. 7) and the piece is held perpendicularly against a revolving cast iron disk (see Fig. 11) under a constant pressure of 1250 grams, while standard quartz sand, between 30 and 40 mesh, is fed on the disc to act as the abrasive agent. At the end of 1,000 revolutions the loss in weight is determined and the test repeated with the specimen reversed.

Hardness........H equals 20—1-3 w.

Where W equals loss in grams per 1,000 revolutions. In interpreting results of this test all rocks below 14 are called soft; from 14 to 17, medium; above 17, hard.

TOUGHNESS, OR RESISTANCE TO IMPACT.

This test is made on 25 mm. x 25 mm. (0.98 in) rock cylinders with an impact machine (see Fig. 9) especially designed for the purpose, instead of a flat end plunger resting on the test piece as in the cementation test, a plunger with the lower bearing surface of spherical shape, having a radius of 1 cm. (0.4 inch) is used. It can be seen that the blow as delivered through a spherical end plunger approximates as nearly as practicable the blows of traffic. The test piece is adjusted so that the center of its upper surface is tangent to the spherical end of the plunger, and the plunger is pressed firmly upon the test piece by two spiral springs which surround the plunger guide rods. The hammer weighs 2 kg. and is raised by a small cable, and released by a trigger coming in contact with projecting pins spaced 1 cm. on centers. The test consists of a 1 cm. fall of the hammer for the first blow, and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to cause failure is used to represent the toughness.

In interpreting results of this test, those rocks which run below 13 are called low; from 13 to 19, medium; and above 19, high.

IMPACT MACHINE FOR TESTING TOUGHNESS OF ROCK.

The motor "C" drives the cable "S" by means of a worm gear, this raises the crosshead "M" which carries the 2 Kg. hammer "N".

The trigger on the crosshead "M" strikes projecting pins on the frame, which are spaced one cm. apart. This releases the hammer "N" which falls upon the spherical plunger "O" and the blow is transmitted to the test specimen which rests on the anvil "W".

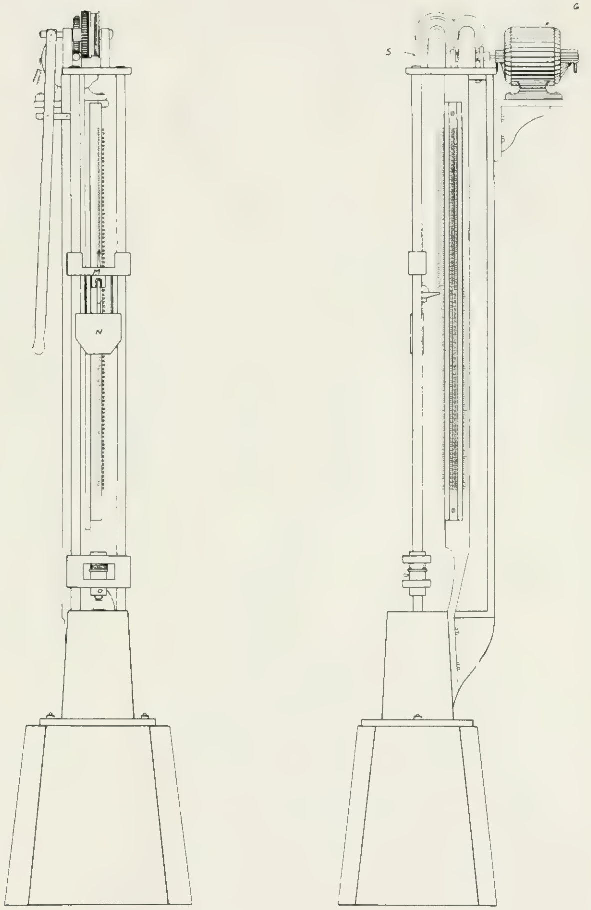


Fig 9

Impact Machine For Testing Toughness of Rock.

ABSORPTION TEST.

A piece of the abraded stone weighing from 50 to 70 grams was dried in an oven for 5 hours then weighed and placed in water for 96 hours, it was then wiped off on the outside and weighed again and the amount of water absorbed per cubic foot was computed.

RESULTS OF INVESTIGATION, BY COUNTIES.

ADAIR COUNTY.

Only one sample was received from this county, No. 50, blue limestone with a very close dense texture, sharp fracture, and containing a few large crystals of calcite. This sample comes from a quarry on the bank of Big Creek near Kirksville, the crushed stone being used on the macadam streets of Kirksville. The tests show a low coefficient of wear, 6.3; and a good cementing value, 33.4; hardness of 12.9; and a low resistance to impact, 7.0.

ANDREW COUNTY.

Sample 18, gray limestone with fine grain, having a rough fracture, and containing streaks of calcite; taken from Rheinhart's quarry, on the property of Evans Paul, three miles south of Savannah on the C. G. W. R. R. The ledge is about 18 feet thick and the crushed stone has been used in Andrew and Buchanan counties for road metal. Tests show a low coefficient of wear, 5.8; a fair cementing quality, 19.0; hardness of 9.4; and a low resistance to impact, 6.0.

Sample 19, blue limestone of medium close texture, containing streaks of calcite; takes from the quarry of Newton, Whitford and Knight on the farm of E. J. Blakeslee, four and one half miles north of Savannah on the C. G. W. R. R. The ledge is about 30 feet thick and has a large face developed. Crushed stone is shipped to St. Joseph and elsewhere. Tests show a low coefficient of wear, 6.2; good cementing quality, 39.6; hardness of 9.4; and low resistance to impact, 10.0.

Sample 20, brown limestone, known locally as "Butcher Stone", it has a coarse open texture and contains much clay, sand and fossils; taken from the same quarry as sample 19. The ledge is above the blue limestone and is about 4 feet thick. Tests show a very low coefficient of wear, 3.7; a fair cementing value, 23.2; hardness of 5.6, which is very soft; and a very low resistance to impact, 6.0. A poor road metal.

AUDRAIN COUNTY.

The only material received from this County was a sample of blue limestone, No. 242, taken from Telford foundation on North Jefferson street in Mexico after twenty years of service. It came from a quarry in the northwest part of the City of Mexico. Tests show a medium coefficient of wear, 8.2; and an excellent cementing value, 112.0. Hardness and toughness tests were not made.

BARTON COUNTY.

Sample 109, bituminous limestone, very dark color, crystalline structure, coarse texture, very rough fracture, containing large crystals of calcite and numerous fossils; taken from the bank of Dry Fork of Spring River, five miles east of Lamar. Tests show a low coefficient of wear, 5.0; good cementing value, 41.0; very soft, 1.99; and a low resistance to impact, 6.0.

Sample 110, flint rock (known locally as "nigger heads"), it shows all gradations from flint to chalk, porous and pitted near the outside, colored red by oxide of iron, and contains numerous fossils. This sample was taken from the roadside three miles out from Lamar. It is found in scattering deposits in the southeast corner of the county and has been used to some extent on the streets of Lamar with only fair success. Tests show a medium coefficient of wear, 10.3; good cementing value, 34.4; very hard, 19.1; and a low resistance to impact, 11.0.

Creek gravel is found in the southeastern part of the county, but no sample of this was obtained.

BATES COUNTY.

Limestone is the only road material found in this county, it occurs in abundance in the north half of the county and there are scattering outcrops in the south part, the southern part being largely sandstone and shale.

Sample 103, gray argillaceous limestone with fine grained dense texture, containing a little sand; from William Herring's quarry at the east edge of Butler. Tests show a medium coefficient of wear 10.0; good cementing value, 26.0; hardness of 11.7; and a very low resistance to impact, 3.0.

Sample 104, gray limestone, coarse grained crystalline structure, contains numerous fossils and a small percent of clay, and has a ragged fracture. Obtained from a quarry on Chas. Argenbright's farm on the north side of Butler. The tests show a low coefficient of wear, 6.1; good cementing value, 50.4; hardness of 13.4; and a low resistance to impact, 11.0.

BENTON COUNTY.

Sample 100, a coarse grained crystalline limestone with grayish brown color; it contains many fossils and has a smooth sharp fracture and close texture. This sample comes from Thompson's quarry about one mile up the Osage River from Warsaw. This rock does not occur in very thick strata but grades off into "cotton rock"; it is found only along the Osage River. The tests show a low coefficient of wear, 5.3; a fair cementing value, 16.6; hardness of 9.6; and a low resistance to impact, 7.0.

Sample 101, hard-pan gravel or "hill gravel"; taken from the roadside south of the Osage River near Warsaw; consisting of chert mixed with about 50 per cent of red clay. It exists in great quantities all over the County and is much used for surfacing roads. It has an excellent cementing value, 167.8.

BOLLINGER COUNTY.

The road materials found in this county are limestone which is plentiful in the west part of the county, but has not been used to any extent on the roads; and creek gravel which occurs plentifully in the north and west parts of the county and has been used some for road building.

Sample 194, magnesian limestone containing clay along the stratification planes, has a rough sharp fracture, and is easily broken into cubes; taken from an old quarry one half miles west of Lutesville on the property of A. J. Englehart. Tests show low coefficient of wear, 7.0; good cementing value, 46.6; hardness of, 9.1, which is soft; and a low resistance to impact, 6.0.

Sample 195, creek gravel from Crooked Creek one quarter of a miles east of Lutesville on the property of Geo. E. Conrad; consists chiefly of hard chert worn smooth by water; and has a fair cementing value, 14.0.

BOONE COUNTY.

The limestone quarries of this County produce three kinds of stone which have been used for road building, these are all found in the same quarry; the white crystalline limestone generally occurs in the top ledges; the blue crystalline limestone below the white and in the deeper parts of the quarry; and the chert or flint occurs in seams and pockets all through the limestone ledges. Creek gravel is found in abundance in the small streams and the old toll roads in this county have been constructed of this material mainly.

Sample 69, blue limestone with a coarse crystalline structure, containing many fossils; taken from a quarry one half mile southwest of Columbia owned by John A. Stewart. Tests show a low coefficient of wear, 5.4; excellent cementing value, 132.4; hardness of 10.1, which is soft; and a low resistance to impact, 7.0. Too soft for road metal except for the lightest traffic.

Sample 70, white limestone with a coarse crystalline structure, containing many fossils; taken from the same quarry as sample 69. Tests show a very low coefficient of wear, 3.5; good cementing value, 42.6; hardness of 13.3; and a low resistance to impact 9.0.

Sample 234, chert or flint rock, very hard and brittle; from the same quarry as 69 and 70. Tests show a low coefficient of wear, 6.8; cementing value of 17.4. No tests were made for hardness or toughness. This sample required 105 grams of water to produce a paste in the ball mill for moulding briquettes, 90 grams is usually sufficient for most stones.

Sample 238, creek gravel from Hinkson Creek just above the bridge on Providence Road about one mile south of Columbia. Tests show a high resistance to wear, the coefficient being 15.4; and a cementing value ranging from 24.0, with 50% of Hinkson sand, to 80.6, with 25% of Hinkson sand and without sand, using only the larger pieces of gravel broken so as to pass a ¼-inch mesh, the cementing is 32.0. While the average cementing value would be considered good the authors believe the hardness of the stones and their rounded shape prevents them from binding readily under traffic until a sufficient amount of loam and clay has been carried onto the road to form a binder. With a finely crushed softer rock of good cementing value, such as the blue limestone found in this county, for a binder, it is believed a good permanent road can be constructed with this gravel.

BUCHANAN COUNTY.

Sample 16, limestone from a quarry at St. Joseph, owned and operated by Young Brothers. An eleven foot face is exposed and the crushed stone from this quarry is being used for concrete and road metal in St. Joseph and vicinity. Tests show a medium coefficient of wear, 10.2; good cementing quality, 48.6; hardness of 13.4; and a low resistance to impact, 7.0.

Sample 17, a light gray limestone of fine texture, has a rough irregular fracture, and contains numerous pits of sand and clay; taken from the quarry of the St. Joseph Rock Crushing Co. at St. Joseph, on the property of Mrs. D. Mignary. Tests show a low coefficient of wear, 7.7; good cementing quality, 32.2; hardness of 13.8; and a low resistance to impact, 5.0.

BUTLER COUNTY.

The only road materials found in this county are limestone, which has not been used much except for the manufacture of lime; and creek gravel which occurs only in the northwest half of the county and has been used very little on the roads.

Sample 181, calcium magnesian limestone, from Magruder's quarry six miles west of Poplar Bluff on the farm of W. S. Davenport. It has a crystalline structure, close texture with an occasional pit, and has a sharp fracture. Tests show a low coefficient of wear, 6.4; a good cementing value, 42.0; a hardness of 9.9; which is soft; and a low resistance to impact, 8.0.

Sample 182, creek gravel, taken from creek five and one half miles west of Poplar Bluff on the farm of J. M. Wills; consists chiefly of fragments of chert free from sand; and has a low cementing value, 9.0.

CALDWELL COUNTY.

Sample 38, blue limestone with close texture and rough fracture; from a quarry one half mile north of Breckenridge owned by the Breckenridge Stone Co. The quarry has fifteen foot face exposed, and is on a spur track of the C. B. & Q. R. R. Tests show a low coefficient of wear, 6.1; good cementing value, 35.0; hardness of 12.3; and a low resistance to impact, 7.0.

Sample 39, gray limestone with coarse texture and rough ragged fracture; containing pits of sandstone, large crystals of calcite, and many fossils; from the same quarry as sample 38, existing above it in a six foot ledge. Tests show a low cofficient of wear, 4.7; good cementing value, 29.2; hardness of 8.3; and a low resistance to impact, 9.0.

Sample 40, bituminous limestone with a coarse open texture, mixed with sand and clay; from a quarry one half mile north of Breckenridge, owned by Mont Maddoux. The ledge is six feet thick and has black streaks all through it. This stone is used for rip rap on the C. B. & Q. R. R. Tests show a very low coefficient of wear, 0.8; and a low cementing value, 9.0; hardness of 3.4; and a low resistance to impact, 7.0.

CAPE GIRARDEAU COUNTY.

The road materials found in this county are blue limestone, which is quarried near Cape Girardeau and used on the roads and streets and for railroad ballast and riprap; white limestone quarried near Cape Girardeau and used mostly for buildings; a brown sandstone from the river bluffs north of Cape Girardeau and creek gravel which occurs plentifully in the north half of the county.

Sample 190, blue limestone from quarry two miles south of Cape Girardeau owned by Edward Hely. Tests show a medium coefficient of wear, 9.1 which is rather high for limestone; a fair cementing value, 20.6; hardness of 13.8; and a medium resistance to impact, 14.5. These tests indicate a medium road material, which is above the average limestone but probably too soft for heavy traffic.

Sample 191, brown sandstone, from quarry one half mile north of Cape Girardeau owned by Edward Regenhardt. It is fine grained, medium close texture, sharp fracture, and has been much used for building purposes. Tests show a low coefficient of wear, 7.5; a good cementing value, 40.6, which is high for sandstone; hardness of 12.5; and a low resistance to impact, 12.5, which is rather high for sandstone.

Sample 192, white limestone from quarry one mile northwest of Cape Girardeau owned by John Himmelberger. Tests show very low coefficient of wear, 5.7; good cementing value, 39.0; hardness of 10.7, which is soft; and a low resistance to impact, 12.0.

Sample 193, creek gravel, from creek bed one and one half miles northwest of Cape Girardeau on the property of Maple Wilson; composed of chert and free from earth and sand; and has a good cementing value, 32.2.

CARROLL COUNTY.

Samples of three kinds of limestone and one sample of sandstone were received from this county.

Sample 1, light gray sandstone with a coarse texture, the grains of sand being cemented together with lime, with occasional spots of brown sandstone; taken from the quarry of the Carroll County Sandstone Co. near Miama. This stone is used extensively for buildings, the Carroll County Court House being built of it; but would be a poor road metal, being entirely too soft; so the tests were made for comparison only. The tests show a very low coefficient of wear, 2.8; good cementing value, 51.6; hardness of 5.5, which is very soft; and very low resistance to impact, 7.0.

Sample 2, brown limestone, containing a large percentage of sand and occasional streaks of clay, the cementing material is iron oxide, silica and lime, it has a close texture and a rough fracture; it was obtained from a three foot ledge outcropping in the road two miles west of Carrollton on the "Ground Hog Road." The tests show a medium coefficient of wear, 9.3; a good cementing value, 26.6; hardness of 12.9; and a low resistance to impact, 10.0.

Sample 3, gray limestone, rough and nodular, containing pits of clay and sand, also large crystals of calcite imbedded in the finer mass, it has a rough irregular fracture and numerous cleavage planes running at various angles to the stratification planes. This sample was obtained from the farm of John Bailey three miles northwest of Carrollton. The ledge is only about one foot thick and extends over a large area in the north central part of the county. Tests show a low coefficient of wear, 7.1; a fair cementing value, 14.0; hardness of 10.6 which is soft; and a very low resistance to impact, 7.0.

Sample 4, dark blue limestone, very dense, with occasional streaks of calcite imbedded in it, has a smooth fracture, and is easily broken into rectangular pieces; obtained from a quarry two and one half miles northeast of Tina, owned by Dr. O. R. Edmonds. This ledge is only about ten inches thick, but above this is another ledge twenty inches thick of similar quality. This stone is quarried for foundations, water tables, and curbing. Tests show a medium coefficient of wear, 12.9; excellent cementing value, 115.8; medium hardness, 14.2; and medium resistance to impact, 16.0. These tests are very high for limestone and indicate a good road metal for medium traffic.

CARTER COUNTY.

The road materials found in this county are granite, which is found at only one quarry on Current River; limestone occurs in large quantities, but has not been used on the roads; creek gravel is also plentiful, but has not been much used on the roads.

Sample 170, red granite, from an old quarry on Current River three and one half miles southeast of Van Buren on the farm of Mrs. M. Carter. Tests show a high coefficient of wear of, 14.8; good cementing value, 34.2; hardness of 19.3, which is very hard; and medium resistance to impact, 14.0. These tests indicate a good road metal.

Sample 171, magnesian limestone of close texture, containing pits which give it a honeycombed appearance; taken from R. R. cut at bluff near south end of wagon bridge between Chicopee and Van Buren. Tests show a low coefficient of wear, 7.4; fair cementing value, 19.8; hardness of 9.7, which is soft; and low resistance to impact, 11.0.

Sample 172, creek gravel taken from Current River one hundred yards below highway bridge at Van Buren, on the property of the Mo. Lumber and Mining Co.; consists of pebbles of chert, dolomite, and quartzite; and has a fair cementing value, 17.8.

CASS COUNTY.

Sample 78, white limestone with medium close texture and having a little clay mixed throughout; from Glen Parker's quarry one mile north of Pleasant Hill. The quarry has been opened to a depth of eight feet. Tests show a low coefficient of wear, 6.4; good cementing value, 43.8; hardness of 13.7; and a low resistance to impact, 6.0.

Sample 102, white limestone with close dense texture and a sharp fracture, from a quarry near Harrisonville owned by Frank Runneberger. Tests show a low coefficient of wear, 6.9; good cementing value, 45.2; hardness of 9.3; and a low resistance to impact, 12.0.

East of Pleasant Hill and Harrisonville and south of Harrisonville the formation is mostly sandstone and shale, the rest of the county has an abundance of limestone.

CEDAR COUNTY.

Sample 108, gray crystalline limestone (Burlington limestone) having a coarse dense structure and a rough fracture; from the property of R. L. Hutton on Walnut Creek two miles northwest of Eldorado Springs. This stone is found in greater quantities in the eastern part of the county. The tests show a low coefficient of wear, 4.9; a fair cementing value, 16.0; hardness of 9.8; and a low resistance to impact, 8.0.

Magnesian limestone is found in the eastern part of the county along the streams and creek gravel is found in the streams of the eastern part but no samples of these were secured.

CHARITON COUNTY.

Sample 64, gray limestone with dense texture; obtained from the farm of C. A. Huffman, three miles northwest of Brunswick. The ledge is exposed in a cut on the Wabash R. R., no quarry exists here. Tests show a medium coefficient of wear, 12.8; good cementing value, 28.2; hardness of 10.3, which is soft; and a low resistance to impact, 11.0.

Sample 65, light brown sandstone with open texture and very soft; obtained from a quarry two miles south of Salisbury owned by Albert Hawkins. The ledge is ten feet thick. Tests show a very low coefficient of wear, 1.6; fair cementing value, 21.0; hardness of 3.1; and low resistance to impact, 5.0. A very poor road material.

CLARK COUNTY.

Sample 47, white chalky limestone having a smooth fracture and containing some streaks of brown sandstone. The specimen was weathered but was sound on the inside and seemed to have been deposited in very thin layers that adhere quite firmly together. Occurs in a four foot ledge, above ledge from which sample 48 was taken, in many places on John Willard's farm near the main line of the Santa Fe R. R. near Dumas. No quarry exists here but there is an abundance of stone of easy access. The tests show a high coefficient of wear, 13.8; good cementing value, 51.0; hardness of 10.8; and a low resistance to impact, 8.0.

Sample 48, blue limestone with very close texture and a rough fracture, and somewhat decomposed; from the same bluffs as sample 47. From 10 to 20 foot face of this stone is exposed. Tests show a medium coefficient of wear, 8.7; good cementing value, 69.8; medium hardness, 14.3; and low resistance to impact, 5.0.

Sample 49, very dark limestone with very close texture and having clay disseminated throughout; from Sam Casey's quarry on Fox River four miles north of Kahoka. The ledge outcrops for some distance along Fox River, and this stone has been used on the streets of Kahoka. Tests show medium coefficient of wear, 9.3; good cementing value, 50.8; hardness of 12.7; medium resistance to impact, 14.0.

CLAY COUNTY.

Sample 8, blue limestone having a sharp splintery fracture, dense texture, with occasional veins of pure calcite running through it; from an old quarry belonging to W. Bagley, one and one half miles northeast of Liberty, near the road and on the bank of a small stream. The ledge is about three feet thick and rests on a bed of shale. This rock has been used on the streets of Liberty. Tests show a high coefficient of wear, 13.8; a fair cementing value, 22.2; medium hardness, 14.7; and a low resistance to impact, 10.0. The hardness and coefficient of wear are quite high for a limestone.

Sample 9, brownish gray limestone, having a smooth concoidal quartzlike fracture, with large crystals of calcite imbedded in a very close ground mass; from a quarry on the Wabash R. R. just west of South Liberty, owned by S. H. Atwood. This stone occurs irregularly in the top ledges of the quarry. Tests show a medium coefficient of wear, 9.7; a fair cementing value, 14.2; hardness of 13.8; and a low resistance to impact, 8.0.

Sample 10, blue limestone with close texture, interspersed with veins and crystals of calcite, and having a smooth fracture; from the same quarry as sample 9. The face of this quarry is from twenty to thirty feet and the crushed stone is used for ballast, concrete, and road work. Tests show a low coefficient of wear, 7.5; a fair cementing value, 14.2; hardness of 11.4; and a low resistance to impact, 6.0.

Sample 11, gray limestone, close fine texture, rough fracture, and containing a small percentage of clay and sand; from the Ettison quarry, three quarters of a mile southwest of Excelsior Springs. The quarry has about an eight foot face exposed and the crushed stone is used for macadam streets in Excelsior Springs. Tests show a low cofficient of wear, 7.0; good cementing value, 27.0; medium hardness, 14.1; and a low resistance to impact, 6.0.

Sample 12, limestone from a newly opened quarry in Excelsior Springs, owned by John Carr. Quarry has four feet face exposed and the stone is used on the macadam streets. Tests show medium coefficient of wear, 8.0; good cementing value, 36.4; medium hardness, 16.2 and a resistance to impact of 12.0.

CLINTON COUNTY.

Sample 14, limestone from J. H. Anderson's quarry on the farm of Gov. Ingles just north of Plattsburg. The ledge is ten inches thick and the stone is used for foundations and concrete aggregate. Tests show a medium coefficient of wear, 9.5; good cementing value, 43.1; hardness of 12.5; and a low resistance to impact, 8.0.

Sample 15, gray limestone, close texture, containing a small percentage of sand and clay, also streaks and large crystals of calcite; from the same quarry as sample 14, being in ledge above 14. This stone is found all along the bluffs overlooking the Smith Fork River.

Tests show medium coefficient of wear, 11.8; good cementing value, 61.0; hardness, 12:5; and a low resistance to impact, 7.0.

COLE COUNTY.

Sample 94, magnesian limestone (dolomite) with fine grain but open texture, from a quarry on Miller Street in Jefferson City, owned by the state and operated by Joseph Pope. This is the prevailing stone of the county and is found in abundance in most parts of the county. It is used for most of the building and street work in Jefferson City. The tests show a medium coefficient of wear, 8.2; and a fair cementing value, 24.6; hardness of 4.7, which is soft; and a low resistance to impact, 4.0.

Sample 95, creek gravel from Moreau Creek four miles south of Jefferson City on Moreau Road and near Greenberry Bridge; composed of chert mixed with about 40% of sand. Moreau Road is surfaced with this gravel and is in excellent condition. The tests show a good cementing value of 42.6.

COOPER COUNTY.

There is an abundance of limestone in this county and some gravel in the southern part, but no sample of gravel was obtained.

Sample 78, gray limestone with coarse grained crystalline structure and very rough fracture; from the city quarry at Boonville about three quarters of a mile down the Missouri Pacific track from the main street. This rock is used on the macadam streets of Boonville and for making concrete. It is typical of the limestone along the Mo. River in Cooper and Moniteau Counties. The tests show a medium coefficient of wear, 8.2; good cementing value, 25.2; hardness of 8.6, which is soft; and a low resistance to impact, 6.0.

Sample 79, white crystalline limestone containing large crystals of pure calcite and many fossils. It has a rough fracture. It comes from a quarry on the county road three or four miles south of Boonville, adjoining the property of Chas. Grathwohl. Tests show a very low coefficient of wear, 3.3; very good cementing value, 92.2; hardness of 7.6; and a low resistance to impact, 5.0.

CRAWFORD COUNTY.

Limestone occurs over the county but has not been used on the roads; used for lime. "Hill gravel" is found all over the county in beds from two to ten feet thick and has been used to a limited extent on the roads. Creek gravel occurs in nearly all parts of the county and has been used some on the roads.

Sample 154, silicious limestone with coarse texture and rough fracture, containing some clay and considerably pitted; taken from a quarry one quarter of a mile northeast of Frisco depot in Steelville, owned by D. A. Houston. Tests show a very low coefficient of wear 3.6; good cementing value, 25.6; hardness of 1.3, which is very soft; and a low resistance to impact, 8.0.

Sample 155, "hill gravel" taken from hillside one mile northeast of Steelville on land of Chas. Stough; consists of fragments of chert, very hard and showing no signs of disintegration, and has a fair cementing value, 12.2.

Sample 156, creek gravel, taken from creek one half mile southwest of Steelville on property of J. C. Campbell; consists chiefly of chert and dolomite, free from sand, and has a good cementing value, 44.6.

DADE COUNTY.

Sample 124, gray crystalline limestone with a dense close texture and good fracture; from a quarry one mile from South Greenfield, owned by the Ash Grove White Lime and Cement Co. This has been quite an important quarry but is not in use at present. This stone is found in abundance throughout the southeast quarter of the county. Tests show a low coefficient of wear, 5.8; good cementing value, 31.0; hardness of 7.4; and a very low resistance to impact, 5.0.

Sample 125, brown sandstone mixed with dolomite and flint known locally as flint boulders. The dolomite was badly disintegrated and honeycombed and the flint was cracked in many places. It is found in abundance all over the county. This sample was picked up on the roadside between Greenfield and South Greenfield. Tests show a low coefficient of wear, 4.8; a fair cementing value, 12.8; hardness of 12.3; and a low resistance to impact, 9.0.

Creek gravel is found in abundance in all the streams and is the material generally used for road surfaces, no sample of this was obtained.

DAVIESS COUNTY.

Limestone is the only road material found in this county, four samples of which were sent in from the vicinity of Gallatin.

Sample 29, blue limestone, fine grained, close texture, with occasional veins of calcite running through it; from a quarry in the north part of Gallatin owned by William Rulong. The stone is being used for concrete aggregate. Tests show a medium coefficient of wear, 9.7; fair cementing value, 17.0; hardness of 13.8; and a medium resistance to impact, 14.5. These tests are above the average for limestone.

Sample 30, blue limestone from an old quarry one mile south of Gallatin owned by Wood H. Hamilton. The top ledge is eight inches thick, the second eleven inches thick and the third fourteen inches thick. Tests show a medium coefficient of wear, 8.7; good cementing value 38.6; hardness of 13.4; and a low resistance to impact, 11.0.

Sample 31, light gray limestone with fine close texture, having streaks of clay and sand; from a quarry owned by the city of Gallatin and near the Rock Island depot. A small crusher is operated here and the stone is used on the streets of Gallatin. Tests show a medium coefficient of wear, 8.8; a fair cementing value, 19.6; medium hardness, 14.7; and a low resistance to impact, 8.0.

Sample 73, white limestone of close texture; from the quarry of Robinson and George at Gallatin, owned by A. R. George. The sample was crushed before shipping and was considerably abraded by shipment. Tests show a medium coefficient of wear, 8.0; good cementing value, 64.0; hardness of 10.7; and medium resistance to impact, 14.0.

DEKALB COUNTY.

Limestone is the only road metal found in this county, three samples of which were secured in the vicinity of Maysville.

Sample 35, clayey limestone, buff color, close fine texture, and a sharp flinty fracture; from a quarry on J. C. Sparling's place two miles southeast of Maysville. It is found in ledges ten to twelve inches thick and it becomes harder on exposure to the weather. Tests show medium coefficient of wear, 11.7; a fair cementing value, 16.6; medium hardness, 14.3; and a low resistance to impact, 10.0.

Sample 36, blue limestone of coarse texture but very dense, contains large crystals of calcite, and has a rough ragged fracture; from the same quarry as No. 35. Ledge is from two to three feet thick. Tests show medium coefficient of wear, 8.8; a fair cementing value, 14.8; hardness of 11.3; and a low resistance to impact, 8.0.

Sample 37, dark gray limestone, fine grained, containing deposits of sandstone and clay, and having a ragged fracture; from a quarry one mile east of Maysville, owned by Jacob Winter. The ledge is twelve to eighteen inches thick. This stone occurs in several parts of the county. The tests show a medium coefficient of wear, 8.0; a fair cementing value, 11.6; hardness of 10.2; and a low resistance to impact, 7.0.

DENT COUNTY.

The road materials found in this county are limestone, which occurs plentifully but has not been much used for either building or road purposes; "hill gravel", which is plentiful and said to be highly satisfactory when it has been used on the roads; and creek gravel, which occurs plentifully only in the streams of the eastern portion of the county, the Meramec River affording an almost inexhaustable supply of this material.

Sample 150, limestone with close texture and rough fracture; from a quarry three quarters of a mile northeast of Salem, owned by Chas. Lust. Tests show a medium coefficient of wear, 9.5; a fair cementing value, 22.2; hardness of 11.5; and low resistance to impact, 12.0.

Sample 151, "hill gravel", taken from roadside three quarters of a mile northeast of Salem; consisted chiefly of fragments of chert mixed with clay; and showed a good cementing value, 31.2. This material occurs in beds from five to eight feet thick.

Sample 152, creek gravel, taken from the Meramec River six miles northeast of Salem on the farm of L. H. Dent; consisted of pebbles of chert, dolomite and rhyolite, very hard and smooth, and sand. Test showed a very good cementing value, 75.8.

FRANKLIN COUNTY.

Sample 142, white magnesian limestone from quarry owned by the city of Washington, located one mile west of the Missouri Pacific depot; this stone has been used in the macadam streets of Washington and in some buildings, and occurs in considerable quantities in this vicinity. The tests show a medium resistance to wear, 8.3; a fair cementing value, 19; hardness of 12.6, which is soft, and a medium resistance to impact, 15.

Sample 143, white limestone containing sand and clay disseminated throughout, has a rough fracture and presents a somewhat pitted appearance; taken from a quarry one mile east of Rock Island depot at Union, owned by L. B. Bruck. It occurs in quantities and is used principally for buildings. The tests show a low resistance to wear, 4.4; a fair cementing value, 23.6; hardness of 12.1, which is soft; and a low resistance to impact, 10; it is therefore considered a poor road material.

Sample 144, bank gravel taken from gravel bank about one and one half miles east of the court house at Union, owned by Jesse Ekey; consists of chert, quartsite and sand, mixed with red clay; occurs in large quantities and is much used as a road material. It has a good cementing value, 41.0 probably due to the red clay.

GASCONADE COUNTY.

Sample 140, magnesian limestone (cotton rock) from a quarry owned by the City of Hermann one mile south of the Missouri Pacific depot; it has a fine grained opened texture with clay disseminated throughout, rough fracture, and the stratification planes well defined; occurs extensively and is used on the streets of Hermann and on the roads around Hermann. The tests show a low coefficient of wear, 6.8; a good cementing value, 58.4; hardness of 12.7, which is soft, and a low resistance to impact, 9.0.

Sample 145, magnesian limestone from a quarry on the farm of Gustave Holychuch, three miles north of Owensville; it has a fine grained open texture with clay disseminated throughout, smooth fracture; occurs in quantities and is used both for road and building purposes. The tests show a low resistance to wear, 6.3; a good cementing value, 71.2; medium hardness, 15.2; and a medium resistance to impact, 13.5.

Sample 146, creek gravel taken from creek three miles north of Owensville on the farm of Gustave Holychuch; it consists of hard pebbles of chert and dolomite mixed with sand. The test showed a good cementing value, 36.2. This gravel occurs plentifully in the southern part of the county, but has not been much used for road building purposes.

GENTRY COUNTY.

Sample 26, gray limestone with a close fine texture, having clay disseminated throughout, and a smooth sharp fracture; from Dan Blatcher's place, one and one half miles south of Evona. This rock is used in Albany for concrete aggregate, but is not extensively quarried. Tests show a low coefficient of wear, 5.9; excellent cementing quality, 105.8; hardness of 8.2; and a low resistance to impact, 10.0.

Sample 27, brownish gray limestone with rather open texture, containing streaks of calcite, and having a smooth sharp fracture; from the farm of S. M. Austin, three quarters of a mile southwest of McFall. The ledge is two or three feet thick and lies beneath a bed of sandstone. Tests show a medium coefficient of wear, 12.1; good cementing quality, 54.6; hardness of 12.7; and a medium resistance to impact, 14.5.

Sample 28, dark blue limestone with a dense close texture, having occasional large crystals imbedded in it, and a smooth sharp fracture; from the same quarry as 27 and lies beneath it. The ledge is only eight or ten inches thick. Tests show a medium coefficient of wear, 9.0; good cementing value, 32.6; medium hardness, 14.1; and a low resistance to impact, 7.0.

GREENE COUNTY.

Sample 126, gray crystalline limestone, coarse grained, containing many large crystals of calcite so interlocked as to give it a granitic appearance. It has a rough fracture and a few suture joints. Obtained from Horton's quarry in Springfield. This stone is found in various localities over the county. The tests show a low coefficient of wear, 5.2; good cementing value, 46.2; hardness of 6.8; and a low resistance to impact, 5.0.

Sample 127, cherty dolomite, or surface flint rock, containing all gradations from dolomite to chalk, white for the most part, the red iron oxide stains showing occasionally. Picked up on roadside three miles west of Springfield. It is found all over the county scattered loosely over the fields and piled up on the roadsides. It has been used on several miles of road near Springfield and is very satisfactory. Tests show a low coefficient of wear 5.9; a fair cementing value, 12.4; medium hardness, 15.5; and a resistance to impact of 12.5. For remarks on the hardness and toughness tests of such material see Jasper county. Sample 112.

Sample 128, gravel from James River eight miles southwest of Springfield; consists chiefly of rounded pebbles of chert, very hard and ranging in size from two inches in diameter to fine sand; and the test showed a cementing value of 25.6.

This gravel was used in building the government road from Springfield to the National Cemetery. This road is in fine condition. Gravel similar to this is found in all of the good sized creeks in the county.

GRUNDY COUNTY.

Sample 34, brown limestone with coarse texture, rough fracture, and mixed with sand and clay; from a quarry one mile southwest of Trenton, owned by Harry Hertzog. A face of fifteen feet is exposed in this quarry. It is used for macadam streets and concrete, and is said by the County Highway Engineer to be a fair sample of the limestone found in this county. Tests show a low coefficient of wear, 6.1; good cementing value, 26.8; hardness of 6.7; and a low resistance to impact, 6.0.

HARRISON COUNTY.

Sample 23, limestone from an old quarry belonging to Dean Speery located southwest of Bethany. Four foot ledge exposed, more beneath, little stripping is necessary. Tests show a low coefficient of wear, 5.9; excellent cementing value, 112.6; hardness of 10.2; and low resistance to impact, 9.0.

Sample 24, limestone from a quarry about three quarters of a mile southwest of Bethany on the property of A. H. Flint, leased to the city of Bethany, the crushed rock being used for concrete. The ledge is ten feet thick and has eight feet of stripping. Tests show a low coefficient of wear, 6.9; good cementing value, 33.8; medium hardness, 16.8; and a medium resistance to impact, 13.0.

HOLT COUNTY.

Sample 21, gray limestone, fine texture, rough fracture, and contains sand, clay, and large crystals of calcite; from a small quarry owned by Robert Walters, one and one half miles south of Oregon. The crushed rock is used to a small extent on the streets of Oregon. The tests show a low coefficient of wear, 7.1; excellent cementing value, 103.8; hardness of 9.8; and a low resistance to impact, 7.0.

Sample 22, blue limestone, close texture, splintery fracture, with large crystals of calcite imbedded, and clay disseminated throughout; from a small quarry in Forest City owned by Ira Hall. The ledge is ten feet thick, but requires considerable stripping. Tests show a low coefficient of wear, 7.6; good cementing value, 51.4; hardness of 11.4; and medium resistance to impact, 13.0.

HOWELL COUNTY.

The road materials available in this county are creek gravel, which occurs plentifully in all stream beds; and the surface or field stones of chert which are plentiful in most localities.

Sample 75, chert, field stones from Fruitville Farm Co. The tests show a low coefficient of wear, 5.9; an excellent cementing value, 206.8; a hardness of 10.2, which is soft; a low resistance to impact, 9.

Sample 76, similar to 75, and from same locality. Tests show low coefficient of wear, 4.9; excellent cementing qualities, 277.4; hardness of 9.6, which is soft; and low resistance to impact, 7.5.

Sample 165, creek gravel taken from creek one quarter of a mile west of Willow Springs on the farm of D. S. Ferguson; consists of chert and cherty dolomite, mixed with sand; is said to be a fair representative of the gravel that occurs in the stream beds all over the county; and has been used to a very limited extent on the roads. Tests show a good cementing value, 37.2. This gravel is probably much harder and tougher than samples 75 and 76 and would wear much better, but as the field stones show such excellent cementing qualities it would seem that a combination of gravel and finely crushed stones would make a better road material than either one taken separately.

Sample 166 is a white sandstone from a quarry three and one half miles west of Willow Springs owned by I. D. McLucas. This stone is used for building only, and has no qualities to recommend it as a road material, so the tests were made only for comparison. Its coefficient of wear is exceedingly low, 0.8; a very low cementing value, 4.4; very soft, 4.4; and its resistance to impact is exceedingly low, 2.0.

IRON COUNTY.

There is a large variety of road material in this county. Red granite occurs abundantly in the vicinity of Graniteville and the refuse from the granite quarries has been used on some of the roads near Graniteville. Porphyry is plentiful in many parts of the county. Refuse from the old iron mines at Pilot Knob; there is a considerable amount of this material, but it has not been used for road purposes. Limestone is plentiful in the northern part of the county and creek gravel occurs in the stream beds all over the county. At Shepard's mountain near Ironton there is a large amount of so-called "rotten granite" which seems to be an excellent binder for road surfaces.

Sample 212, red granite with large interlocking crystals, from the Syenite Granite Co's. quarry at Graniteville. Tests show a medium coefficient of wear, 10.4; good cementing qualities, 40.8; medium hardness, 14.4; and a medium resistance to impact, 19.0.

Sample 213, red hematite iron ore, close texture, metallic luster and very heavy, taken from the dump of old iron mine on north side of Pilot Knob Mountain about one mile northeast of Ironton. There is a good deal of this mine refuse at this place. Tests show a low coefficient of wear, 7.1; good cementing value 36.2; hardness of 17.2; and a medium resistance to impact, 13.0.

Sample 214, magnesian limestone, medium close texture, somewhat pitted giving it a slightly honeycombed appearance, it has a sharp rough fracture and a sandy touch; taken from hillside one mile southwest of Graniteville on the property of Pilot Knob Mining Co. Tests show a low coefficient of wear, 7.7; good cementing value, 61.0; hardness of 12.8; and medium resistance to impact, 13.5.

Sample 215, porphyry, a very dense, hard, ingenous rock having a fine ground mass with large dark crystals imbedded, sharp fracture, and red color; taken from hillside three and one half miles northwest of Ironton on the property of Pilot Knob Mining Co. Tests show a medium coefficient of wear, 11.4; very good cementing value, 78.8; medium hardness, 15.3 and a high resistance to impact, 20.5. These tests indicate an excellent road material.

Sample 216, creek gravel, taken from creek bed near the Iron Mountain R. R. about one half mile north of Ironton; consists chiefly of chert and quartz mixed with sand; and has a fair cementing value, 22.8.

Sample 240, "rotten granite", reddish in color and easily broken in pieces by the hands, from Shepard's Mountain one quarter of a mile northwest of Ironton. It has an excellent cementing value, 390.0, which indicates that it would be an excellent binding material. This sample was sent in by Curtis Hill, State Highway Engineer.

JACKSON COUNTY.

This county has an abundance of limestone all over the county and a great many macadam roads have been built of this material.

Sample 83, grayish blue limestone with a medium close texture and ragged fracture, containing numerous deposits of pure calcite, which has a weakening effect on the stone. Taken from the upper strata of a quarry on the east side of Independence, owned by G. W. Shaw. The exposed face of this quarry is thirty five feet and the crushed stone is being used on the roads in the vicinity of Independence. The tests show a low coefficient of wear, 5.8; good cementing value, 65.5; hardness of 9.9; and a low resistance to impact, 8.0.

Sample 84, bluish gray limestone of medium close texture, containing a large percentage of clay deposited in the layers throughout. Taken from the lower strata of the same quarry as sample 83. The tests show a low coefficient of wear, 7.3; good cementing value, 25.4; hardness of 13.8; and a low resistance to impact, 6.0.

Sample 85, blue flinty limestone with a dense texture and sharp fracture; from an old quarry along the road on Sugar Creek about three miles northwest of Independence. This quarry was opened about 1900 to obtain rock for a macadam road in that vicinity and the road built of this rock is said to be still in good condition. The tests show a low coefficient of wear, 7.8; excellent cementing quality, 107.8; medium hardness, 14.5; and a low resistance to impact, 9.5.

Sample 86, blue limestone, composed of large crystals of calcite imbedded in a fine ground mass which contains a large per cent of clay, the fracture is ragged. From Wagner's quarry on the Blue Springs road six miles east of Independence. This stone is now being used on the Blue Springs Road. The tests show a low coefficient of wear, 6.7; good cementing value, 27.0; hardness of 6.8, which is soft; and a low resistance to impact, 4.0.

JASPER COUNTY.

Sample 111, pit gravel from near Spring River and the gravel road, on the property of Geo. McDaniel two and one half miles east of Carthage. Sample consisted of chert and cherty dolomite mixed with about 20% of clay; and showed a good cementing value of 83. This gravel is found in many localities throughout the county, but not in such abundant quantities as on the hillsides along Spring River; and it is a favorite road material in the county. This same gravel without the clay is found in all the stream beds, but no sample of this creek gravel was obtained.

Sample 112, cherty dolomite, known locally as "cotton rock." It contains all gradations from dolomite to chalk, is very porous and the outside is colored red with iron oxide. It occurs in loose fragments and boulders in quantity in various places; this sample was taken from the Ammon's Farm near Carthage. This stone is crushed and used on macadam roads. The tests show a low coefficient of wear, 3.9; a low cementing value, 10.0; hardness of 11.1; and a medium resistance to impact, 15.0. In such material as this the cores for making the hardness and toughness tests are necessarily cut from the larger and more solid parts of the stone, and therefore the hardness and toughness tests probably run considerably higher than the average hardness and toughness of such material.

Sample 114, gray crystalline limestone with uniform close texture, rough fracture, has a few suture joints and will take a high polish. From the Carthage Superior Marble and Limestone Co.'s quarry at Carthage. This stone is widely distributed over the county and it is largely used as a building stone. It is known throughout the country as Carthage stone. The tests show a low coefficient of wear, 6.8; good cementing value, 41.6; hardness of 12.1; and a low resistance to impact, 7.0.

Sample 239, "Chats", a finely crushed flint rock, which is the refuse from the lead and zinc mines. It is a hard flinty material and is largely used on macadam roads; but owing to the sample being finely crushed the only test that could be made was for cementing value, which is 25.0.

JEFFERSON COUNTY.

Limestone is plentiful in the south part of the county, and has been crushed and used on the roads; and creek gravel is plentiful in most parts of the county.

Sample 219, magnesian limestone with a fine grained open texture, rough fracture, white in color, has clay between the stratification planes along which it readily parts; taken from quarry one mile southeast of Hillsboro, owned by Joseph Hoken. Tests show medium coefficient of wear, 8.2; fair cementing value, 15.6; hardness of, 6.8; and a low resistance to impact, 5.0.

Sample 220, creek gravel, taken from creek bed about one hundred yards west of Iron Mountain R. R. station at Victoria; consists of pebbles of chert and cherty dolomite free from sand and earth, and has a fair cementing value, 22.8.

JOHNSON COUNTY.

The only road metal found in this county is limestone; there is no gravel in the county. Warrensburg is situated on an immense sandstone ridge, but this sandstone is too soft for road purposes.

Sample 88, blue limestone with close texture and sharp smooth splintery fracture, containing a few large crystals of calcite imbedded; from a quarry on Judge Bradley's farm about two and one half miles northeast of Warrensburg. This sample was sent in by David Mohler, the County Highway Engineer, and is typical of the rock in the central part of the county. It occurs in ledges from one to eight feet thick, generally about three feet, and it lies just above the coal beds. The tests show a medium coefficient of wear, 8.5; a good cementing value, 36.4; medium hardness, 15.8; and a medium resistance to wear, 13.0.

KNOX COUNTY.

Sample 51, a coarse crystalline limestone of dark color and having a rough fracture; taken from a small quarry on the farm of John

W. Vaughn, two miles southwest of Edina. This sample is a representative of the stone of Knox county. Tests show a low coefficient of wear, 4.8; good cementing quality, 55.8; hardness of 8.5, which is soft; and a low resistance to impact, 11.0 These tests indicate that this stone is too soft and brittle, for road metal, except for very light traffic.

LACLEDE COUNTY.

Sample 131, cherty dolomite having a close texture, and containing numerous small cavities and cracks running through it; taken from a quarry on the property of Mrs. E. L. Greenlief in Lebanon. This stone is found throughout the county. Tests show a low coefficient of wear, 5.1; good cementing value, 51.2; medium hardness, 15.5; and a medium resistance to impact, 13.0.

Sample 132, creek gravel from creek on the farm of Mr. Shoemaker three and one half miles from Lebanon; consists chiefly of pebbles of chert and about 30% of sand, it is very fine, 75% passing a ½ inch mesh. It has not been used on the roads. Tests show a good cementing value, 56.

Surface chert or flint rock is also found in great abundance; for tests on this material see report on Pulaski and Webster counties.

LA FAYETTE COUNTY.

Sample 81, blue shaley limestone having a nodular structure and irregular fracture; from a quarry one half mile west of Lexington, owned by William Greer. This rock occurs in ledges from three to four feet thick and lies just above coal beds; it is also found in the hills facing the Missouri River. The sample was much weathered and badly disintegrated. Tests show a low coefficient of wear, 4.8; good cementing value, 71.4; hardness of 8.9; and a low resistance to impact, 6.0.

Sample 82, gray limestone, known as Bethany limestone, open texture, rough fracture, and containing a little iron oxide, from an old quarry on the Laura A. Nowell Estate two miles south of Lexington. This quarry shows an exposed face of seven feet but appears to go much deeper and covers an area of one square mile. This same stone is found in large quantities on the Greenton and Powell ridge from Odessa to Greenton. The tests show a medium coefficient of wear, 9.1; good cementing value, 51.4; hardness of 13.7; and a low resistance to impact, 7.0.

LAWRENCE COUNTY.

Sample 121, gray crystalline limestone, coarse grained, having a rough fracture and somewhat crumbly; from a quarry on the Gibbs estate a short distance north of Mt. Vernon. A thirty foot ledge is exposed and contains pockets of chert. Tests show a very low coefficient of wear, 3.4; good cementing value, 34.6; hardness of 10.5; and low resistance to impact, 4.0.

Sample 122, cherty dolomite, containing all gradations from dolomite to chalk. The chert is pitted and honeycombed and red in color along its parting planes. The stone in general is a grayish blue color. This sample was taken from the property of Sherman Mundy, one half mile north of Mt. Vernon. It is found as boulders scattered in fragmental deposits on the upland. Tests show a very low coefficient of wear, 2.4; a good cementing value, 37.6; medium hardness, 15.8; and a low resistance to impact, 11.0. For a note of the hardness and toughness tests of such material, see Jasper county Sample 112.

Sample 123, creek gravel from Mill Creek just north of Mt. Vernon; consists of pebbles and fragments of chert mixed with sand and clay. The fragments show some signs of disintegration. It has a cementing value of 36.

Pit gravel, or hill gravel, is also found in this county; but no sample of this was obtained.

LEWIS COUNTY.

Only one sample, No. 50, was obtained from this county; it is a blue laminated limestone taken from the farm of George Onsley near Canton; no quarry exists here, but there is an abundance of loose rock which has been used on the streets of Canton. Tests show a low coefficient of wear, 6.8; a good cementing quality, 31.4; hardness of 8.4, which is soft; and a low resistance to impact, 11.5. These tests indicate that this stone is too soft and brittle for a good road metal.

LINCOLN COUNTY.

Sample 62, white limestone with large interlocking crystals and a few large fossils; from the quarry of the Crystal Carbonate Lime Co. at Elseberry, Missouri, which has a thirty-five foot quarry face exposed. The sample was of crushed stone, so seventy-five pieces were required for the abrasion test and the stone had been considerably abraded by shipment. Tests show medium coefficient of wear, 12.9; excellent cementing value, 107.0; hardness of 13.5, which is high for limestone; and a low resistance to impact, 11.0.

Sample 63, clayey limestone with rather open texture; from a quarry owned by John Taylor, located near the St. L. &. H. R. R. track at Troy. The ledge is five feet thick and the stone is used on the streets of Troy. Tests show a coefficient of wear of 7.9; good cementing value, 52.0; hardness of 11.4; and a low resistance to impact, 10.0.

LINN COUNTY.

Sample 41, blue limestone with close fine texture; taken from a quarry on the farm of P. D. Bundas five miles north of Linneus. The ledge is three feet thick and free from seams. It has never been used for road purposes. Tests show a medium coefficient of wear, 11.1; good cementing value, 38.8; medium hardness, 14.6; and low resistance to impact, 11.0. With the exception of cementing quality, these tests are above the average for limestone.

Sample 42, blue clayey limestone with close texture and ragged fracture; obtained from a four foot ledge on the farm of Charles Schoess one mile west of Linneus. Tests show a low coefficient of wear, 5.9; a fair cementing value, 13.2; hardness of 8.5; and a low resistance to impact, 9.0.

LIVINGSTON COUNTY.

Sample 71, brown sandstone, coarse grains cemented together with iron oxide and lime; from the farm of J. N. Roberts, two miles north of Mooresville. This stone exists in limited quantities and is used for foundations only. The tests show a very low coefficient of wear, 2.1; excellent cementing value, 139.4; hardness, 0.0, very soft; and very low resistance to impact, 4.0. This stone could not be used on road surfaces except as a binder for a harder rock or gravel.

Sample 72, white limestone having a close texture, smooth fracture and containing a small per cent of clay disseminated throughout; obtained from the farm of Jas. N. Roberts, two miles north of Mooresville. This stone has not been used for road purposes, but a large quarry could be developed here, the ledge is 10 feet thick. The tests show a medium coefficient of wear, 9.7; a very good cementing value, 93.4; hardness of 13.8, which is high for limestone; and a low resistance to impact, 8.0.

MACON COUNTY.

Sample 53, blue limestone having a fine dense texture and splintery fracture; from a quarry one and one half miles southwest of Macon owned by William Ring. The ledge is two and one half feet thick and the stone has been used principally for concrete aggregate. Tests show a medium coefficient of wear, 9.5; good cementing quality, 34.8; hardness of 11.7; and a low resistance to impact, 8.0

MADISON COUNTY.

There is quite a variety of road material in this county. Limestone is plentiful over the county, but has not been much used on the roads; rhyolite and granite are plentiful in the vicinity of and to the west of Fredericktown; kaolin, or rotten granite, occurs in large quantities three and one half miles west of Fredericktown; "chats" from the lead mines and creek gravel.

Sample 196, silicious limestone, mineral bearing, containing green oxide of copper, red oxide of iron, and said to contain traces of gold, it contains numerous small pits which are generally empty, some being filled with iron oxide. Sample taken from hillside three and one half miles west of Fredericktown on the property of W. J. Holliday. Tests show a medium coefficient of wear, 9.3; good cementing value, 56.0; hardness of 16.2, which is medium; and low resistance to impact, 8.0.

Sample 197, rhyolite, from same locality as sample 196; consisting of quartz crystals imbedded in a fine ground mass, the texture is very dense, the fracture sharp and rough, and the color is pink. Tests show a very high resistance to wear, 22.1; good cementing value, 49.2; hardness, 18.1; and a high resistance to impact, 26.0.

Sample 198, kaolin, or rotten granite, the orthaclase and mica have disintegrated leaving a porphyritic structure with quartz imbedded in the decomposed matrix; it is soft and has a chalky touch. This sample was taken from a hill three and one half miles west of Fredericktown on the farm of W. J. Holliday, a large hill here is composed almost wholly of this material. At the point where the sample was secured a quantity of the material had been blasted out exposing a face about 20 feet high. The rock exposed in this face varied in color from almost pure white to a pink. It has been used to a small extent on roads and is said to make a good surface. The tests show a very low coefficient of wear, 2.6; very good cementing value, 78.4; hardness of 9.2; and a low resistance to impact, 6.5. These tests indicate that this material would make an excellent binder for a harder road material.

Sample 199, red granite, composed of small crystals and having a rough fracture; taken from hillside one mile west of Fredericktown on the property of George Lampher, Jr. Tests show a high coefficient of wear, 16.0; fair cementing value, 20.8; medium hardness, 16.8; medium resistance to impact, 19.0.

Sample 200, creek gravel, from creek in Fredericktown on the property of Z. J. Berryman; consists chiefly of chert and sand; and has a fair cementing value, 12.8.

Sample 202, "chat", from Mine La Monte Lead and Smelting Co. two and one half miles west of Fredericktown; it is crushed very fine and has a low cementing value, 9.6.

MARIES COUNTY.

The road materials found in this county are creek gravel, which occurs plentifully, but not used much on the roads; the so-called "hill gravel" which is a very brittle flint mixed with a considerable amount of clay, found on hillsides in beds from one foot to several feet in thickness, it is said to be more plentiful in the east than in the west half of the county, and has been the principal road building material in the county; also pitted dolomite which occurs plentifully and is used extensively for buildings, but not much for roads.

Sample 147, "hill gravel" taken from public road one half mile east of Vienna; consists of chert, badly disintegrated and very brittle, mixed with clay. Tests show a good cementing value, 26.4.

Sample 148, creek gravel, from Fly Creek one mile west of Vienna; consists of chert, cherty dolomite, and quartzite, free from sand. Test shows a low cementing value, 5.8.

Sample 149, magnesian limestone (pitted dolomite); from quarry two miles north of Vienna owned by Andrew Weidinger; it has an open texture, nodular structure, containing clay and sand around the nodules, and is very brittle. Tests show a very low coefficient of wear, 0.8; a good cementing value, 36.0; hardness of 5.1, which is very soft; and a low resistance to impact, 6.5. This stone might be used as a binding material with the creek gravel, but its other qualities are too poor for road purposes.

MARION COUNTY.

The road materials found in this county are limestone, which is abundant in the vicinity of Palmyra and Hannibal; creek gravel, which is abundant along the entire course of the North River, a distance of forty eight miles; and a hard-pan, or bank gravel.

Sample 54, white limestone with a coarse crystalline structure and containing fossils and deposits of chert; taken from "North Cut" on the C. B. & Q. railroad two and one half miles north of Palmyra. The ledge is from fifty to seventy-five feet thick, alternating chert, or flint, and limestone. Tests show a low coefficient of wear, 5.8; very good cementing quality, 87.4; hardness of 9.6, which is soft; and a low resistance to impact, 10.0.

Sample 55, creek gravel from North River near Palmyra; consisting of pebbles of sheet limestone and quartz mixed with about 40% of sand. The pebbles are very hard and smooth and range in size from 1½ to ¼ inch in diameter. It has only a fair cementing value, 14.8. This gravel would probably make a good road surfacing material if some of the sand were replaced by finely crushed limestone like sample 54 to make it bind readily.

Sample 56, light gray limestone having a coarse crystalline structure, from a quarry operated by Huston and Bland, located on the high bluff overlooking the Mississippi River just south of Hannibal. This quarry has a face of forty feet and six feet of stripping, and the stone is crushed and used by the city of Hannibal for macadam and concrete. The tests show a low coefficient of wear, 4.6; good cementing quality, 28.2; hardness of 12.6; and a low resistance to impact, 12.5. These tests indicate that the stone is harder and tougher than the average limestone, but its low resistance to wear indicates that it is not a good road material, except for very light traffic.

Sample 77, hard-pan gravel, or bank gravel, taken from a cut on the C. B. & Q. railroad two and one half miles north of Palmyra; it lies just above the ledge of rock from which sample 54 was taken and is recommended by the County Engineer of Marion county as an excellent binder for this stone. It consists of a reddish brown clay mixed with about 40% of chert fragments. The clay is very plastic and sticky when wet and becomes very hard and tough upon drying. It has a very high cementing value, 180.8.

MERCER COUNTY.

Sample 32, blue limestone from an old quarry once operated by the Rock Island R. R. and owned by John Buren, located three or four miles south of Princeton. This sample was taken from the top ledge beneath which was a layer of slate and beneath the slate is a series of ledges of sandy limestone four to ten feet thick, similar to sample 33. Tests show a medium coefficient of wear, 9.1; good cementing value, 41.2; hardness of 13.6; and a low resistance to impact, 7.0.

Sample 33, white limestone, fine close texture, rough fracture, with occasional streaks of sand and clay; from a quarry owned by T. W. Ballew near Princeton. This rock is representative of the rock in this county and it is plentiful. Tests show a medium coefficient of wear, 8.7; good cementing value, 38.0; hardness of 11.8; and a low resistance to impact, 8.0.

MILLER COUNTY.

Sample 96, hard-pan gravel, or "hill gravel", taken from the roadside at north edge of Tuscumbia; consists of fragments of chert badly disintegrated and mixed with a sticky red clay; and has a very remarkable cementing quality, 317. This material occurs throughout the county and has been used for surfacing the road in a rough way, a drag being used.

Sample 97, creek gravel from Osage River at Tuscumbia; consists of chert, cherty dolomite, and quartzite mixed with sand and earth; and has a fair cementing value, 16.4. Gravel is found in abundance in all of the streams of the county; but that found in the smaller streams seems to be made up of larger stones and has not so much sand as that found in the Osage River.

Sample 98, white magnesian limestone or cherty dolomite, known locally as "cotton rock", fine grained and open texture; taken from the roadside one mile south of Eldon on the Tuscumbia road. The same stone is found in the Osage River bluffs and probably in other parts of the county. The tests show a low coefficient of wear, 7.4; good cementing value, 29.4; hardness of 4.1, which is soft; and a low resistance to impact, 5.0.

MONITEAU COUNTY.

The only sample of road material received from this county was creek gravel which is found everywhere in the county and has been used on the roads near California, Mo.

Sample 93, creek gravel, from Brush Creek near California; composed of pebbles and fragments of chert, very hard and smooth; and has a good cementing value, 61.2.

Limestone is plentiful all over the county; that near the Missouri River is like sample 78, Cooper county, and that in the interior of the county is probably like the limestone of Pettis county.

MONROE COUNTY.

Sample 66, white limestone with close texture; from the quarry of William Davis, one mile west of Paris. The quarry has a face of fifteen feet and considerable flint occurs in the limestone. Crushed rock from this quarry is used upon the roads in this locality. Tests show a low coefficient of wear, 4.7; excellent cementing value, 138.8; hardness of 3.5, which is very soft; and a very low resistance to impact, 4.0.

Sample 67, white limestone with open texture and containing streaks of sand and clay and large crystals of calcite; from the quarry of L. Hennings one half mile northeast of Paris. Tests show a low coefficient of wear, 5.1; good cementing value, 37.2; hardness of 5.1, which is soft, and a low resistance to impact, 7.0.

Sample 68, creek gravel from Elk Fork at the Mexico Bridge four miles south of Paris; consists chiefly of chert mixed with limestone, quartz, and sand; it is very fine, more than 50% of it passes a ½ inch mesh, while some pebbles are 2 inches in diameter. It is found in great abundance along Elk Fork, and is used to a great extent upon the roads in the county. It has a good cementing value, 39.

MONTGOMERY COUNTY.

The west and south part of this county are well supplied with limestone. This rock has been used for macadamizing the streets of Montgomery City. Creek gravel is plentiful in the streams of the south and west parts of the county but it has not been used to any extent for road building.

Sample 226, creek gravel from Smith's Branch, at the road crossing three miles southeast of Montgomery City on the property of B. A. Donaldson. It consists chiefly of chert which showed marked signs of wear; and has a fair cementing value, 15.6.

Sample 227, grayish blue limestone with close fine texture resembling that of neat cementing mortar, has a few large crystals of calcite imbedded, and has a smooth sharp fracture; from a quarry three miles southwest of Montgomery City owned by B. A. Donaldson. This stone is used on the roads about Montgomery City. Tests show a low coefficient of wear, 7.5; excellent cementing quality, 117.2; hardness of 4.5, which is very soft; and a low resistance to impact, 5.0.

MORGAN COUNTY.

Sample 99, creek gravel from little Gravois Creek about one and one half miles south of Versailles; consists of chert, dolomite and cherty dolomite; and has a fair cementing value, 23.2. This gravel is found in abundance all over the county and is used almost exclusively for road building. There is also some "hill gravel" in the county which is the same material as the creek gravel with the addition of clay; but no sample of this was obtained. Magnesian limestone is also found in this county but is very soft and has been found unsatisfactory for road purposes.

NEWTON COUNTY.

Sample 115, gray crystalline limestone, close texture, rough fracture, and full of suture joints; from an old quarry on the property of John Martin, just across Hickory Creek east of Neosho. This stone is found all over the county. Tests show a medium coefficient of wear, 8.7; a fair cementing value, 22.8; hardness of 12.8; and a resistance to impact of 12.0.

Sample 116, creek gravel from Hickory Creek near Neosho; composed of pebbles and fragments of chert, very hard and ranging in size from 2 inches in diameter to fine sand; and having a good cementing value, 72.

Pit gravel similar to that found in Jasper county, sample 111, is also found in Newton county.

Sample 117, cherty dolomite, known locally as "cotton rock," and similar to sample 112, containing all gradations from dolomite to chalk. A portion of the sample was honeycombed and pitted and had a reddish brown color. Taken from the roadside about one mile southwest of Neosho. This material is found in large quantities throughout the county. The tests show a very low coefficient of wear, 2.8; good cementing value, 63.2; hardness of 12.5; and a low resistance to impact, 10.0. The badly weathered condition of the sample accounts for the low coefficient of wear. For remarks on the hardness and toughness of this material see Jasper county, sample 112.

OSAGE COUNTY.

There is a plentiful supply of "cotton rock" (limestone) in the north part of the county which has been crushed and used on the roads to a limited extent. Pitted dolomite (Jefferson City formation) occurs plentifully in the south half of the county but has been used only for buildings. Creek gravel is plentiful in most parts of the county and has been used some for road surfacing.

Sample 137, white magnesian limestone, known as "cotton rock", it has a fine open texture, and smooth fracture; taken from quarry, five miles south of Bonnots Mill, owned by August Parting. Tests show a low coefficient of wear, 4.5; good cementing value, 28.4; hardness 6.7, which is very soft; and a very low resistance to impact, 6.0. These tests indicate a low grade road metal.

Sample 138, creek gravel taken from bed of Loose Creek about one half mile south of Loose Creek P. O. on the land of Theodore Parting; it consists of soft pebbles of chert and dolomite and sand, ranging from 2 inches in diameter to fine sand, and has a very good cementing value, 80.2.

Sample 139, magnesion limestone (dolomite), fine grained, medium close texture, nodular structure, with clay disseminated throughout; from Plassmeyer's quarry three miles east of Westphalia. Tests show a low coefficient of wear, 3.9; good cementing value, 43.6; hardness of 9.0, which is soft; and a low resistance to impact, 8.5.

PERRY COUNTY.

There is an abundance of limestone in this county but in most localities it is covered by clay which is from 2 to 15 feet thick, and it has not been extensively used for road building. Creek gravel is plentiful in all of the streams and has been used to a limited extent on the roads.

Sample 224, blue limestone with a very fine grained texture with occasional streaks and crystals of calcite imbedded, has a smooth sharp concoidal fracture, flinty and somewhat brittle, and has clay disseminated throughout. This sample was taken from hillside about 100 yards southwest of residence of Mr. J. F. DeLassus, near Crosstown. Tests show a medium coefficient of wear, 11.4; good cementing value, 32.0; medium hardness, 15.1; and a low resistance to impact, 8.0.

Sample 225, creek gravel from Dry Fork Creek two miles west of Crosstown on the property of John Eichhorn; consists chiefly of fragments and pebbles of cherty dolomite, free from sand; and has a cementing value of 23.2.

PETTIS COUNTY.

Sample 89, lead colored clayey limestone with open texture and sharp fracture; from a quarry two miles north of Sedalia, owned by D. A. Smith. The quarry has an exposed face of about twenty feet.

grading from a flinty blue limestone at the bottom to a yellowish stone at the top not quite so hard. Tests show a medium coefficient of wear, 10.5; very good cementing value, 88.4; hardness of 8.8; and a low resistance to impact, 10.0.

Sample 90, bank gravel, found on top of limestone ledge from which sample 89 was taken, the gravel bed is about four feet thick at this place. It is found in scattering deposits all over the county. It is composed of fragments of chert partially disintegrated and ranging in size from four inches in diameter to fine sand, colored by iron oxide, and mixed with a very sticky red clay. Tests showed an excellent cementing value, 131.6.

Sample 91, grayish blue limestone having a close dense texture, sharp fracture, and free from clay; from a quarry three and one half miles north of Sedalia, owned by Luther Reed. A twelve foot face is exposed in the quarry. This is known as the Burlington limestone. Tests show a low coefficient of wear, 6.1; good cementing value, 40.6; hardness of 11.6; and a low resistance to impact, 10.0.

Sample 92, creek gravel from Spring Creek near Valda on the Warsaw branch of the Missouri Pacific Railroad; it consists almost entirely of pebbles and fragments of chert mixed with a little sand. The pebbles are smooth and hard except parts of the outside which are disintegrated somewhat. Test showed a good cementing value, 33.4.

PHELPS COUNTY.

The road materials found in this county are pitted dolomite and "cotton rock" of the Jefferson City formation, which occur plentifully in the west half of the county and have been used for road building; and creek gravel which is found in all streams throughout the county.

Sample 158, pitted dolomite, a crystalline magnesian limestone of medium close texture and containing pits filled with clay; from a quarry one mile southwest of Rolla owned by Mrs. M. Hoover. Tests show a low coefficient of wear, 6.6; a fair cementing value, 15.8; hardness of 12.7; which is soft; and a low resistance to impact, 12.5.

Sample 161, "cotton rock" a fine grained magnesian limestone with open texture and containing considerable clay disseminated throughout; from same quarry as sample 158, in ledges immediately over it. Tests show a low coefficient of wear, 7.0; a good cementing value, 59.6; hardness of 12.5; and a low resistance to impact, 10.0.

Sample 160, creek gravel from Beaver creek four miles southwest of Rolla on the farm of Edward Pausel; consisted of chert, dolomite, sand and clay; and showed a cementing value of 23.8.

Sample 159, brownish red sandstone from a quarry four miles southwest of Rolla on the farm of Edward Pausel. Tests show extremely low coefficient of wear, 0.9; a fair cementing value, 16.0; very soft, 6.3; and a very low resistance to impact, 3.0. This was not considered as a road building material and the tests are given for comparison only.

PIKE COUNTY.

Sample 60, limestone from a quarry on the property of Walter Sanderson in the northeast part of Bowling Green. The city operates a crusher at this quarry and the stone is used on the streets and for concrete construction. A face of about fifteen feet is exposed in the quarry. The tests show a low coefficient of wear, 64; a fair cementing quality, 20.8; hardness of 12.2; and a low resistance to impact, 8.0.

Sample 61, white limestone of rather coarse texture, containing a few fossils; from the quarry of Wall Goodman and Co., at Louisiana. Crushed rock from this quarry is being used on the streets of Louisiana. There is an inexhaustible supply of this rock along the bluffs of the Mississippi River. The sample was crushed in the quarry and the pieces were so small that 83 of them were used in the abrasion test and the pieces were considerable abraded by shipping. Tests show a medium coefficient of wear, 12.9; fair cementing quality, 23.4; medium hardness, 15.1 and a low resistance to impact, 9.0.

PLATTE COUNTY.

Sample 13, brown limestone with coarse open texture, containing clay and sand; from an outcrop on the C. B. & Q. R. R. south of Weston, where a ledge of about four feet is exposed. This sample was very much decomposed, due to weathering. Tests show a low coefficient of wear, 6.9; good cementing value, 26.2; hardness of 9.9; and a low resistance to impact, 5.0.

POLK COUNTY.

Sample 133, fine grained limestone (dolomite) containing a little clay along the stratification planes, also some chert; obtained from the property of J. Johnson three miles east of Bolivar on the Buffalo road, on the east side of Piper Creek. This stone is found in the entire eastern half of the county. Tests show a low coefficient of wear, 5.6; good cementing value, 33.4; hardness of 11.3; and a low resistance to impact, 7.0.

Sample 134, brownish colored limestone (dolomite), very porous and having numerous stratification planes, between which were thin films of clay causing it to separate easily along these planes; obtained from the property of Mrs. Dizzer, four miles southwest of Bolivar, at roadside near Bear Creek. Tests show a low coefficient of wear, 4.8; good cementing value, 69.2; hardness of 4.5, which is soft; and a low resistance to impact, 10.

Creek gravel is found in all the streams of the county; and there is also some surface flint rock similar to that in Greene county; this is probably more abundant in the eastern part of the county.

PULASKI COUNTY.

The only samples of road material received from this county were surface outcrop of chert, and limestone; but there is probably an abundant supply of gravel in the Gasconade River and its tributaries.

Sample 228, outcrop chert, nodular in structure, honeycombed on the outer edge, and containing numerous pockets of red iron oxide and quartz; sent in by F. A. Muth from Richland. It appears in outcrops on the surface very abundantly. Tests show medium coefficient of wear, 9.1; good cementing value, 45.6; hardness of 10.7; and a resistance to impact of 12.5, which is just below medium.

Sample 229, magnesian limestone, has a rather open texture, irregular rough fracture, and numerous stratification planes in which is a very thin layer of fine sand and clay; sent in by F. A. Muth from the Frank Godfrey quarry on the property of the Frisco R. R. Co., one half mile southeast of Richland. Tests show a low coefficient of wear, 4.7; good cementing value, 35.0; hardness of 13.2; and low resistance to impact, 9.5.

PUTNAM COUNTY.

Sample 45, limestone, coarse grained and containing many fossils; taken from a 28 inch ledge on the property of the Black Bird Coal Co., Sec. 19, T. 66, R. 18, near Unionville. No quarry exists here and this is said to be about the only stone ledge found in the county. The tests show a medium coefficient of wear, 8.5; a fair cementing quality, 24.0; hardness of 11.3; and a low resistance to impact, 9.0.

RALLS COUNTY.

Limestone is plentiful in this county and gravel occurs in all the stream beds in great abundance and has been largely used on the roads.

Sample 57, blue limestone with rather open texture and containing deposits of pyrite; from the R. H. Caldwell quarry one mile east of New London. The ledge is thirty feet thick. Tests show a medium coefficient of wear, 9.3; a fair cementing value, 23.6; medium hardness, 14.6; and a low resistance to impact, 10.0.

Sample 58, creek gravel from Salt River two miles east of New London; consists of chert, limestone, a few pebbles of quartz, and about 45% of sand. The pebbles are very hard and smooth and range in size from 1½ inches to fine sand. Test shows excellent cementing properties, 138, and indicates a good road metal.

Sample 59, white limestone having a coarse granular structure and containing streaks of clay and sandstone; from a quarry three miles north of New London owned by Reglus Watkins. The ledge is twenty feet thick. Tests show a low coefficient of wear, 5.6; good cementing value, 25.2; hardness of 9.8; and a low resistance to impact, 8.0.

RAY COUNTY.

Sample 5, dark blue limestone, known as "mine rock" as it occurs above a three foot vein of coal; obtained from the dump of the Pea Ridge Stone Co. at Richmond, owned by T. J. Graham. Tests show a low coefficient of wear, 6.3; good cementing value, 60.8; medium hardness, 15.3; and low resistance to impact, 10.0.

Sample 6, clayey limestone with a rought nodular structure, containing a few fossils, having a rough fracture and very close fine texture; obtained from a quarry on the farm of C. R. Kirkham one mile north of Orrick. It occurs in ledges about 8 feet thick and outcrops in the hills throughout the southwest portion of the county. Tests show a low coefficient of wear, 6.9; excellent cementing value, 154.6; medium hardness, 14.2; and a low resistance to impact, 6.0.

Sample 7, gray limestone with dense texture and very rough fracture, having streaks of calcite and many fossils imbedded; from the farm of C. R. Kirkham, one mile north of Orrick. It outcrops in ledges from 3 to 8 inches in thickness and is found in the southwest and north parts of the county. Tests show a low coefficient of wear, 6.6; good cementing value, 74.8; hardness of 11.1; and a medium resistance to impact, 14.0.

REYNOLDS COUNTY.

The road materials found in this county are limestone, which is plentiful in the hills along Black River; and an abundance of creek gravel; but neither of these has been used on the roads.

Sample 174, magnesian limestone with close crystalline texture, contains pits filled with sand and has considerable sand disseminated throughout; taken from bluffs on west side of Black River on the farm of C. C. Odell about one quarter of a mile east of Centerville. Tests show a low coefficient of wear, 4.5; good cementing value, 37.6; hardness of 9.8, which is low; and a low resistance to impact, 12.5.

Sample 175, gravel from Black River one quarter of a mile northeast of Centerville on the farm of J. H. Parks; consists chiefly of chert, cherty dolomite, and quartzite, very clean and free from sand. It has a cementing value of 26.6.

RIPLEY COUNTY.

Road materials collected from this county are limestone, which occurs plentifully over the county; chert or flint rock occurs plentifully (except in the "Flat Woods" or swampy district) both as large boulders and as finely disintegrated material; creek gravel occurs in Current River in large quantities; and white sandstone (quartzite) occurs in large quantities in various localities.

Sample 183, dark gray limestone, fine crystalline texture, rough fracture, containing small pits filled with sand and red iron oxide; from cut on Iron Mountain R. R. two miles east of Doniphan. Tests show high coefficient of wear, 17.3; good cementing value, 40.0; medium hardness 16.1, and medium resistance to impact, 14.0. These tests are high for limestone.

Sample 184, chert, colored red by oxide of iron, very brittle, breaking in small fragments under light blows of the hammer; taken from R. R. cut two miles east of Doniphan. Tests show low coefficient of wear, 7.1; good cementing value, 52.6; hardness of 11.6, which is soft; and low resistance to impact, 9.0.

Sample 185, gravel from Current River 200 yards below wagon bridge at Doniphan on the farm of T. L. Wright; consists chiefly of chert and quartzite, very hard and free from sand; and has a fair cementing value, 20.2.

Sample 186, white sandstone, quartzite, taken from the hillside one quarter of a mile northwest of Doniphan on the farm of H. O. Maness. Tests show medium coefficient of wear, 10.5; good cementing value, 29.8; medium hardness, 15.7; and medium resistance to impact, 16.5.

ST. CLAIR COUNTY.

Sample 135, dark gray limestone with coarse texture and rough fracture, containing crystals of calcite; from Hallowell's lime kiln three quarters of a mile northwest of Osceola. Tests show low coefficient of wear, 4.8; good cementing value, 36.2; hardness of 12.7; and a very low resistance to impact, 6.0.

Dolomite is found in the eastern part of the county, but no sample of this was obtained.

Sample 136, creek gravel from the Osage River at Osceola; consisting of small pebbles and fragments of chert mixed with about 30% of earth, the pebbles are very hard and smooth. Test showed a good cementing value, 50.6.

ST. FRANCOIS COUNTY.

Road material is very plentiful in this county and there is a great variety. Granite is plentiful in the vicinity of Knob Lick; creek gravel occurs plentifully in all the streams; "chats" and waste limestone from the mines, which have been the principal road materials used; and porphyry is plentiful in the west part of the county.

Sample 203, red granite with coarse interlocking crystals, from the Gilsonite Granite Co.'s quarry one mile west of Knob Lick; used mostly for paving blocks. Tests show a high coefficient of wear, 16.0; good cementing value, 39.0; hardness 19.0; and a high resistance to impact, 25.5.

Sample 204, gray granite with large interlocking crystals, rough fracture and very hard; from quarry three quarters of a mile west of Knob Lick, owned by Edward Price; used mostly for paving blocks. Tests show very high coefficient of wear, 21.0; fair cementing value, 23.0; hardness of 18.9; and a medium resistance to impact, 17.0.

Sample 205, blue granite with large interlocking crystals, from a quarry one half mile west of Knob Lick owned by Edward Price; used some for dimension stone work. Tests show a medium coefficient of wear, 9.5; a fair cementing value, 21.8; hardness of 12.8, which is soft; and a medium resistance to impact, 16.5.

Sample 206, creek gravel from St. Francois River three miles southwest of Farmington; consists chiefly of chert, quartz and sand; and has a fair cementing value, 11.0.

Sample 207, "chats" from the Doe Run Lead Co.'s mine at Doe Run, near Farmington; it is crushed very fine and has a fair cementing value, 20.8.

Sample 208, mineral bearing limestone, waste from the Doe Run Lead Co.'s mine near Farmington. Tests show a medium coefficient of wear 8.9; a fair cementing value, 21.6; hardness of 10.1, which is soft; and a medium resistance to impact, 13.5.

Sample 209, blue limestone of close texture, containing crystals of calcite, rough fracture; from quarry one quarter of a mile northeast of Court House in Farmington, owned by Alex. Moore; used for road and building purposes. Tests show a medium coefficient of wear, 8.5; good cementing value, 30.6; hardness 13.6; and medium resistance to impact, 15.0. These tests are rather high for limestone.

Sample 211, porphyry, "trap", dark colored, close texture, and rough fracture; from a hill one half mile northwest of Bismark, owned by Fred Driemeyer. Tests show a high coefficient of wear, 14.8; very good cementing value, 89.0; hardness of 19.7; and a medium resistance to impact, 15.0. These tests indicate a good road metal.

STE. GENEVIEVE COUNTY.

The road materials found in this county are limestone, which is plentiful along the bluffs rising on the west side of the Mississippi River bottoms and is being used on the roads; and the streams of the county afford an abundant supply of gravel which has not been used extensively in road building.

Sample 221, white limestone with a uniform crystalline texture, sharp rough fracture, contains numerous stratification planes, and is easily broken onto polygonal blocks; from a quarry two and one half miles southeast of Ste. Genevieve, owned by Clay Siegel. Tests show a medium coefficient of wear, 10.5; good cementing value, 28.6; hardness of 9.9; and a low resistance to impact, 6.0.

Sample 222, creek gravel taken from creek in Ste. Genevieve, five blocks southwest of Frisco depot, near iron bridge, on the property of Conrad Millheiser; it consists of chert and sand; and has a good cementing value, 56.6.

Sample 230, gray limestone, crystalline, with a foliated structure, containing a few fossils and a little sand and clay along the stratification planes; from quarry in Ste. Genevieve owned by William Baumsbark. Tests show a low coefficient of wear, 6.3; good cementing value, 32.8; hardness of 13.7; and low resistance to impact, 12.5.

ST. LOUIS COUNTY.

There is an abundance of limestone for road building in this county and a great many macadam roads have been built of this material; disintegrated chert, known as "silica", is found in the northwestern part of the county; and creek gravel is found in the small streams; for a test on Meramec River gravel see report on Dent County.

Sample 74, blue limestone, from the Sinclair quarry on the estate of George Penn, Jr. at Vigus. Tests show a medium coefficient of wear, 9.3; good cementing value, 53.2; medium hardness, 13.7; and a medium resistance to impact, 15.5. These tests are above the average for limestone. Four other small samples of limestone from four different quarries in St. Louis county had previously been tested in the laboratory and showed a coefficient of wear of 9.3.

Sample 231, disintegrated chert, known as "silica", sent in by J. W. Shields from Centaur Station; it is white in color and very brittle and has a good cementing value, 36.6. This material would probably form a good binder for gravel or other hard road material.

Sample 232, creek gravel, sent in by J. W. Shields from Centaur Station; consists chiefly of pebbles and fragments of very hard chert; and has a fair cementing value, 17.6.

SALINE COUNTY.

This county has comparatively little road material except along Black Water River in the southern part. Two miles northeast of Marshall there is gravel in very limited quantities and limestone is also found in the vicinity of Slater.

Sample 80, gray limestone with a coarse crystalline texture, good fracture and easily broken into rectangular pieces; from Kockmeyer's quarry at Naptonville. Tests show a medium coefficient of wear, 8.2; good cementing value, 45.6; hardness of 9.0; and a low resistance to impact, 5.0.

SCHUYLER COUNTY.

There are no quarries in this county and no ledges exist where quarries could be developed; drift rock, or "nigger heads" exist abundantly all over the county and according to the County Highway Engineer sample 46 is an average of the existing stone.

Sample 46, glacial drift rock consisting of boulders, from four to six inches in diameter, of limestone, red granite, greenstone, sandstone, and quartzite; the feldspars were badly decomposed. These were field stones picked up near Lancaster. The boulders were broken and mixed together and subjected to the abrasion and cementation tests; but the other tests were not made owing to the variety of rocks. The tests show a low coefficient of wear, 5.9; and a good cementing value, 70.6.

SCOTT COUNTY.

The road materials found in this county are "hill gravel" which is plentiful in the north part of the county and has been used considerably on the roads; limestone is not widely distributed but occurs in considerable quantities in the hills of the north part of the county; and distintegrated chert or flint, known as "silica", occurs in large quantities and has been used by the Frisco R. R. for ballast.

Sample 187, "hill gravel", from gravel pit one mile west of Benton on the farm of Mrs. Mary Glastutter; it consists chiefly of pebbles and fragments of very hard chert and has a good cementing value, 38.0.

Sample 188, dark gray crystalline limestone, medium close texture and rough fracture, containing numerous large crystals of calcite; taken from hillside near Ray's Landing on the Frisco R. R. three miles north of Commerce, on the farm of Herman Muach. Tests show a medium coefficient of wear, 8.9; good cementing value, 60.2; hardness of 13.3; and very low resistance to impact, 5.0.

Sample 189, disintegrated chert or flint, known as "silica," has a very fine dense texture, chalky white in color, and easily broken into fragments; taken from R. R. cut about two miles north of Commerce. Tests show a low coefficient of wear, 6.3; good cementing quality, 42.4; hardness 9.9; and a low resistance to impact, 10.0.

SHANNON COUNTY.

The road materials found in this county are rhyolite, which occurs in large quantities in several localities in the eastern part of the county; limestone which is plentiful all over the county; creek gravel is plentiful in stream beds; and surface stones of chert and flint similar to samples 75 and 76 from Howell county.

Sample 167, rhyolite or porphyry, from the Roger's Copper mine one and three quarter miles east of Emminence on the property of the Michigan Cattle Co. Tests show a medium coefficient of wear, 10.0; good cementing quality, 50.0; hardness of 18.6, which is high; and a high resistance to impact, 23.5. These tests indicate a fine road material.

Sample 168, magnesian limestone, from quarry one half mile east of Emminence owned by H. A. Hennon. Tests show a low coefficient of wear, 6.2; good cementing qualities, 40.0; hardness of 10.3, which is soft; and a low resistance to impact, 11.5.

Sample 169, creek gravel, taken from Jack's Fork of Current River one half mile east of Emminence on the farm of Andrew Hawkins; consists chiefly of chert and quartz mixed with sand; and has a fair cementing value, 16.8.

STODDARD COUNTY.

The only road material found in this county is creek gravel, a sample of which was sent in by Mr. O. L. Pulsee, Highway Engineer of Stoddard county.

Sample 233, creek gravel, from the farm of J. W. Covington near Bloomfield; consisting chiefly of pebbles of chert, quartzite, quartz and sand. It has a good cementing value, 30.0.

STONE COUNTY.

Sample 118, white magnesian limestone, fine grained, open texture, uniform structure; from the railroad cut just north of station at Galena. This deposit is of great depth, extending down to the James River one hundred feet or more and as much above. Tests show a low coefficient of wear, 4.8; good cementing value, 44.0; hardness of 6.3, which is soft; and a low resistance to impact, 5.0.

Sample 119, surface flint rock, badly weathered and honeycombed and cracked in many places. The color on the interior was a grayish blue white, the outside is colored red with iron oxide. From the property of Bud Standard, one mile north of Galena, on the road to Clark's Inn. The hills in this locality are all covered with this material left by the disintegration of the surrounding limestone. It is also found mixed with the clay below the surface. The tests show a low coefficient of wear, 7.4; good cementing value, 28.2; medium hardness, 14.6; and a low resistance to impact, 7.0.

Sample 120, blue limestone with close dense texture, sharp smooth fracture, and having streaks of clay running through it; from the property of Bud Standard, one mile north of Galena, on the road to Clark's Inn, near the top of the hills. Tests show medium coefficient of wear, 8.5; good cementing value, 33.6; hardness of 13.3; and a low resistance to impact, 5.0.

There is an abundance of gravel in James River and other streams and "hill gravel" similar to that found in Jasper county occurs in great quantities.

SULLIVAN COUNTY.

The only available stone for road purposes in this county is limestone, two samples of which were received.

Sample 43, shaley limestone containing a large percentage of sand, the bedding planes are very close together and it separates easily along them; taken from between two ledges of sandstone on the highway one mile north of Milan, near the property of A. D. Payne. Tests show very low coefficient of wear, 4.0; very excellent cementing qualities 239.6; hardness of 7.0; and low resistance to impact, 9.0. This stone is too soft even for light traffic, but might be used as a binder for harder material with good results.

Sample 44, limestone with a coarse open texture, from an old quarry one half mile south of Milan, owned and operated by Hiram Grear. Tests show medium coefficient of wear, 8.5; fair cementing value, 20.6; hardness of 12.4; and a medium resistance to impact, 13.5.

TEXAS COUNTY.

The road materials received from this county are magnesian limestone or "cotton rock", which is said to be plentiful over the county; "hill gravel," occuring in beds from two to fifteen feet deep on the hillsides all over the county; and creek gravel. Samples of all these were obtained near Cabool.

Sample 162, magnesian limestone, from a quarry one quarter of a mile east of Cabool on land owned by J. L. Neff, has a close texture, smooth fracture, and is easily broken into rectangular pieces. Tests show a low coefficient of wear, 7.8; a good cementing value, 30.4; a hardness of 12.3, which is soft, and a low resistance to impact, 10.0.

Sample 163, creek gravel, from creek one quarter of a mile east of Cabool; consists of pebbles of very hard chert, and has a low cementing value, 8.6.

Sample 164, "hill gravel," taken from hillside two and one half miles west of Cabool on the farm of Grant and Davis, consists of fragments of chert mixed with clay; it is very hard and has a fair cementing value, 14.4. It is said that in many localities excellent natural road surfaces of this material exist.

VERNON COUNTY.

Road materials in this county are not plentiful; there is little limestone except in the scattered knolls in the northern and western parts. South and east of Nevada the formation is mostly sandstone.

Sample 105, blue limestone with a close dense texture and sharp fracture, containing streaks of calcite disseminated throughout; taken from the top of a large knoll on the farm of Mrs. Fairchild one half mile north of Eve. Tests show a low coefficient of wear, 6.8; good cementing value, 26.4; medium hardness, 16.0; and a low resistance to impact, 6.0.

Sample 106, brown limestone with medium close texture and containing a large percentage of clay disseminated throughout; taken from the same knoll as sample 105; it exists about twenty feet below 105 in a very shattered formation. The tests show a low coefficient of wear, 7.4; a fair cementing value, 24.0; hardness of 6.2; and a low resistance to impact, 9.0.

Sample 107, black limestone, or siderite, very dense and has a sharp fracture; taken from an outcrop at the base of the knoll from which samples 105 and 106 were taken and was covered with red iron oxide. The ledge is not over two feet thick and overlies a bed of coal. Tests show a high coefficient of wear, 13.3; good cementing value, 49.0; medium hardness, 16.9; and a medium resistance to impact, 14.0.

106 and 107 are not found east of Eve; but are plentiful westward to Fort Scott, Kansas, over a strip about two miles wide.

WASHINGTON COUNTY.

Limestone is plentiful all over the county but has not been used much on the roads. Creek gravel is plentiful in the streams and has been used to some extent for surfacing the roads.

Sample 217, silicious limestone, close crystalline texture, the cementing material being silica, has a rough fracture and shows green oxide of copper; from a quarry two miles west of Potosi on property of Lincoln Trust Co. Tests show a low coefficient of wear, 5.4; good cementing value, 40.4; hardness of 13.6; and low resistance to impact, 10.0.

Sample 218, creek gravel from bed of creek one hundred yards south of court house at Potosi on the property of Perry Bass; consists of chert and cherty dolomite mixed with sand and earth; and has low cementing value, 9.0.

WAYNE COUNTY.

The road materials of this county are two granite quarries north of Piedmont where there is a large quantity of spalls that could be crushed for macadam; limestone in the western part of the county in large quantities; and creek gravel is plentiful over the county. Very few macadamized roads have been built.

Sample 177, dark gray granite, from old quarry one and one half miles northeast of Piedmont owned by J. H. Kelly. Tests show a very high coefficient of wear, 22.1; a good cementing value, 69.4;

hardness of 17.9; and a high resistance to impact, 28.0; which indicate an excellent road material.

Sample 178, magnesian limestone, dark gray in color and containing pits filled with sand and red oxide; from a quarry one quarter of a mile north of Piedmont owned by S. A. Bates. Tests show a low coefficient of wear, 5.3; a good cementing value, 26.0; hardness of 10.4, which is soft; and a low resistance to impact, 12.0.

Sample 179, creek gravel, from the bed of McKenzie creek one half mile northeast of Piedmont on the farm of John Jordan; consists of chert, quartzite and andesite, free from earth and sand; and has a fair cementing value, 15.6.

WEBSTER COUNTY.

Sample 129, white limestone (dolomite), fine grained but rather open texture. It is easily broken into rectangular pieces and has a little clay between the stratification planes. Obtained from a quarry four miles northeast of Marshfield on the property of Mrs. Whittaker. It is found throughout the north half of the county and along James River. Tests show a low coefficient of wear, 5.1; good cementing value, 60.4; very soft, 0.0; and a low resistance to impact, 6.0. These tests indicate a poor road metal.

Sample 130, cherty dolomite, known as flint rock, containing pockets of sand, badly pitted and honeycombed and the outer edges were badly disintegrated, being of a chalky nature and colored with iron oxide; taken from the property of Mrs. Whittaker four miles northeast of Marshfield. It occurs in large quantities all over the county as surface or field stones. Tests show a very low coefficient of wear, 3.9; good cementing value, 74.6; medium hardness, 14.4; and medium resistance to impact, 17.0.

Gravel is found in all the streams in this county, but no samples were obtained.

WORTH COUNTY.

Sample 25, limestone from an old quarry on the farm of O. P. M. Mills six miles east of Grant City, on Grand River; the ledge is three and one half feet thick. This is about the only kind of rock found in the county and it has not been used to any extent on the roads. The tests show a very high coefficient of wear, 25.0; good cementing quality, 74.0; hardness of 8.5; and a low resistance to impact, 9.0. This very high coefficient of wear should be regarded as doubtful until confirmed by another test, as the test for hardness does not indicate such wearing quality.

TABULATION OF RESULTS.

NUMBER.	NAME.	COUNTY.	Percent of Wear	French coeff. of Wear.	Cementing Value.	Hardness	Toughness	Specific Gravity	Weight per cu. ft. —solid form	Water absorbed in lbs. per cu. ft.
1	Sandstone	Carroll	14.2	2.8	51.6	5.5	7	2.28	142.5	7.13
2	Limestone	Carroll	4.3	9.3	26.6	12.9	10	2.67	166.9	1.50
3	Limestone	Carroll	5.7	7.0	14.0	10.6	7	2.69	168.1	0.67
4	Limestone	Carroll	3.1	12.9	115.8	14.2	16	2.69	168.1	0.39
5	Limestone	Ray	6.3	6.3	60.8	15.3	10	2.62	163.8	2.81
6	Limestone	Ray	5.8	6.9	154.6	14.2	6	2.62	163.8	0.29
7	Limestone	Ray	6.0	6.6	74.8	11.1	14	2.66	165.3	0.03
8	Limestone	Clay	2.9	13.8	22.2	14.7	10	2.72	170.0	1.02
9	Limestone	Clay	4.1	9.7	14.2	13.8	8	2.62	163.8	2.45
10	Limestone	Clay	5.3	7.5	14.2	11.4	6	2.69	168.1	1.37
11	Limestone	Clay	5.7	7.0	27.0	14.1	6	2.66	165.3	1.49
12	Limestone	Clay	5.0	8.0	56.4	16.2	12	2.63	164.3	2.02
13	Limestone	Platte	5.8	6.9	2.62	9.9	5	2.51	156.9	7.82
14	Limestone	Clinton	4.7	9.5	43.2	12.5	8	2.63	164.3	0.86
15	Limestone	Clinton	3.4	11.8	61.0	12.5	7	2.63	164.3	0.59
16	Limestone	Buchanan	3.9	10.2	48.6	13.4	7	2.71	169.4	0.76
17	Limestone	Buchanan	5.2	7.7	32.2	13.8	5	2.68	167.5	0.51
18	Limestone	Andrew	6.9	5.8	19.0	9.4	6	2.63	164.4	0.94
19	Limestone	Andrew	6.4	6.2	39.6	9.4	10	2.60	162.5	2.93
20	Limestone	Andrew	10.7	3.7	23.2	5.6	6	2.43	151.9	6.23
21	Limestone	Holt	5.6	7.1	103.8	9.8	7	2.63	164.4	1.17
22	Limestone	Holt	5.4	7.6	51.4	11.4	13	2.62	163.8	1.80
23	Limestone	Harrison	6.8	5.9	112.6	10.2	9	2.45	153.1	1.96
24	Limestone	Hanison	5.8	6.9	33.8	16.8	13	2.40	150.0	10.40
25	Limestone	Worth	1.6	25.0	74.0	8.5	9	2.69	168.0	1.96
26	Limestone	Gentry	6.7	5.9	105.8	8.2	10	2.68	167.5	1.51
27	Limestone	Gentry	3.3	12.1	54.6	12.7	14.5	2.45	153.1	5.21
28	Limestone	Gentry	4.4	9.0	32.6	14.1	7.0	2.65	165.6	1.33
29	Limestone	Daviess	4.1	9.7	17.0	13.8	14.5	2.65	165.6	2.50
30	Limestone	Daviess	4.6	8.7	38.6	13.4	11	2.69	168.0	1.21
31	Limestone	Daviess	4.5	8.8	19.6	14.7	8	2.64	165.1	0.84
32	Limestone	Mercer	4.4	9.1	41.2	13.2	7	2.64	165.1	2.44
33	Limestone	Mercer	4.6	8.7	38.0	11.8	8	2.67	166.9	0.68

34	Limestone	Grundy	6.5	6.1	26.8	6.7	6	2.64	165.1	2.64
35	Limestone	Dekalb	3.4	11.7	16.6	14.3	10	2.65	165.8	2.65
36	Limestone	Dekalb	4.5	8.8	14.8	11.3	8	2.66	165.3	0.21
37	Limestone	Dekalb	5.0	8.0	11.6	10.2	7	2.79	174.2	3.22
38	Limestone	Caldwell	6.5	6.1	35.0	12.3	7	2.51	156.9	2.65
39	Limestone	Caldwell	8.5	4.7	29.2	8.3	9	2.62	163.8	2.94
40	Limestone	Caldwell	46.2	0.8	9.0	3.4	7	2.15	134.5	5.18
41	Limestone	Linn	3.6	11.1	38.8	14.6	11	2.68	167.5	0.54
42	Limestone	Linn	6.8	5.9	13.2	8.5	9	2.65	165.6	1.41
43	Limestone	Sullivan	9.9	4.0	239.6	7.0	9	2.56	160.0	3.04
44	Limestone	Sullivan	4.7	8.5	20.6	12.4	13.5	2.59	161.9	4.40
45	Limestone	Putnam	4.7	8.5	24.0	11.3	9.0	2.70	168.8	2.36
46	Glacial Drift	Schuyler	6.8	5.9	70.6	...	...	...	....	....
47	Limestone	Clark	2.9	13.8	51.0	10.8	8.0	2.59	161.9	0.84
48	Limestone	Clark	4.6	8.7	69.8	14.3	5.0	2.78	173.8	0.96
49	Limestone	Clark	4.3	9.3	50.8	12.7	14.0	2.59	161.9	2.59
50	Limestone	Lewis	5.9	6.8	31.4	8.4	11.5	2.64	165.1	2.81
51	Limestone	Knox	8.4	4.8	55.8	8.5	11.0	2.59	161.9	1.78
52	Limestone	Knox	6.3	6.3	33.4	12.9	7.0	2.73	170.6	0.12
53	Limestone	Macon	4.2	9.5	34.8	11.7	8.0	2.70	168.8	0.79
54	Limestone	Marion	6.9	5.8	87.4	9.6	10.0	2.58	161.3	1.97
55	River Gravel	Marion	...	...	14.8	...	...	...	....	....
56	Limestone	Marion	8.6	4.6	28.2	12.6	12.5	2.68	167.7	1.93
57	Limestone	Ralls	4.3	9.3	23.6	14.6	10.0	2.56	160.0	3.08
58	River Gravel	Ralls	...	...	138.0	...	...	...	....	....
59	Limestone	Ralls	7.2	5.6	25.2	9.8	8.0	2.68	167.7	2.61
60	Limestone	Pike	6.2	6.4	20.8	12.2	8.0	2.62	163.8	3.20
61	Limestone	Pike	3.1	12.9	23.4	15.1	9.0	2.64	165.2	2.82
62	Limestone	Lincoln	3.1	12.9	107.0	13.5	11.0	2.71	169.2	1.61
63	Limestone	Lincoln	5.1	7.9	52.0	11.4	10.0	2.70	168.8	3.04
64	Limestone	Chariton	3.2	12.8	28.2	10.3	11.0	2.64	165.1	0.35
65	Sandstone	Chariton	25.0	1.6	21.0	3.4	5.0	2.22	138.8	11.10
66	Limestone	Monroe	8.6	4.7	138.8	3.5	4.0	2.52	157.5	1.80
67	Limestone	Monroe	7.9	5.1	37.2	5.1	7.0	2.56	160.0	6.65
68	River Gravel	Monroe	...	...	39.0	...	...	...	....	....
69	Limestone	Boone	7.4	5.4	132.4	10.1	7.0	2.63	164.4	1.18
70	Limestone	Boone	11.3	3.5	42.6	13.3	9.0	2.65	165.8	2.58
71	Sandstone	Livingston	18.8	2.1	139.4	0.0	4.0	2.12	132.5	10.30
72	Limestone	Livingston	4.1	9.7	93.4	13.8	8.0	2.65	165.6	1.08
73	Limestone	Daviess	5.0	8.0	64.0	10.7	14.0	2.68	167.5	1.37
74	Limestone	St. Louis	4.3	9.3	53.2	13.7	15.5	2.68	167.5	0.25
75	Chert	Howell	6.7	5.9	206.8	10.2	9.0	2.56	160.0	1.79
76	Feldstone (chert)	Howell	8.2	4.9	277.4	9.6	7.5	2.36	147.5	5.02
77	Hard-pan Gravel	Marion	...	...	180.8	...	...	...	....	....
78	Limestone	Cooper	4.9	8.2	25.2	8.6	6.0	2.65	165.6	0.09

TABULATION OF RESULTS.

NUMBER.	NAME.	COUNTY.	Percent of Wear	French coeff. of Wear.	Cementing Value.	Hardness	Toughness	Specific Gravity	Weight per cu. ft. —solid form	Water absorbed in lbs. per cu. ft.
79	Limestone	Cooper	12.1	3.3	92.2	7.6	5.0	2.63	164.4	0.81
80	Limestone	Saline	4.9	8.2	45.6	9.0	5.0	2.61	163.1	1.15
81	Limestone	Lafayette	8.4	4.8	71.4	8.9	6.0	2.65	165.6	1.24
82	Limestone	Lafayette	4.4	9.1	51.4	13.7	7.0	2.67	166.9	3.00
83	Limestone	Jackson	6.9	5.8	65.5	9.9	8.0	2.59	161.9	2.43
84	Limestone	Jackson	5.5	7.3	25.4	13.8	6.0	2.57	160.6	2.60
85	Limestone	Jackson	5.1	7.8	107.8	14.5	9.5	2.65	165.6	1.57
86	Limestone	Jackson	5.9	6.7	27.0	6.8	4.0	2.67	166.9	1.17
87	Limestone	Cass	6.2	6.4	43.8	13.7	6.0	2.60	162.5	1.92
88	Limestone	Johnson	4.7	8.5	36.4	15.8	13.0	2.66	166.5	1.33
89	Limestone	Pettis	3.8	10.5	88.4	8.8	10.0	2.64	162.9	4.56
90	Gravel	Pettis	...	...	131.6	...	...	...	....	....
91	Limestone	Pettis	6.6	6.1	40.6	11.2	7.0	2.63	164.4	0.16
92	Creek Gravel	Pettis	...	...	33.4	...	...	...	....	....
93	Creek Gravel	Moniteau	...	...	61.2	...	...	...	....	....
94	Dolomite	Cole	4.9	8.2	24.6	4.7	4.0	2.58	161.3	5.65
95	Creek Gravel	Cole	...	...	42.6	...	...	...	....	....
96	Hard-pan Gravel	Miller	...	...	317.0	...	...	...	....	....
97	River Gravel	Miller	...	...	16.4	...	...	...	....	....
98	Dolomite	Miller	5.4	7.4	29.4	4.1	5.0	2.39	149.4	6.01
99	Creek Gravel	Morgan	...	...	23.2	...	...	...	....	....
100	Limestone	Benton	7.5	5.3	16.6	9.6	7.0	2.56	160.0	1.63
101	Hard-pan Gravel	Benton	...	...	167.8	...	...	...	....	....
102	Limestone	Cass	5.8	6.9	45.2	9.3	12.0	2.52	158.7	0.21
103	Limestone	Bates	4.0	10.0	26.0	11.7	3.0	2.62	163.8	0.23
104	Limestone	Bates	6.5	6.1	50.4	13.4	11.0	2.67	166.9	0.38
105	Limestone	Vernon	5.9	6.8	26.4	16.0	6.0	2.71	169.3	0.20
106	Limestone	Vernon	5.4	7.4	24.0	6.2	9.0	2.52	158.7	3.33
107	Limestone	Vernon	3.0	13.3	49.0	16.9	14.0	2.88	180.0	0.04
108	Limestone	Cedar	8.2	4.9	16.0	9.8	8.0	2.67	166.9	0.05
109	Limestone	Barton	8.0	5.0	41.0	1.9	6.0	2.58	161.3	1.29
110	Flint	Barton	3.7	10.3	34.4	19.1	11.0	2.46	153.8	4.64

111	Pit Gravel	Jasper	...	...	83.0	...	...	...	....	....
112	Dolomite	Jasper	10.2	3.9	10.0	11.1	15.0	1.82	113.8	3.34
114	Limestone	Jasper	5.9	6.8	41.6	12.1	7.0	2.64	165.0	1.15
115	Limestone	Newton	4.6	8.7	22.8	12.8	12.0	2.67	166.9	0.65
116	Creek Gravel	Newton	...	...	72.0	...	...	...	....	....
117	Dolomite	Newton	14.3	2.8	63.2	12.5	10.0	2.08	130.0	10.27
118	Dolomite	Stone	8.1	4.8	44.0	6.3	5.0	2.71	169.6	5.08
119	Flint	Stone	5.4	7.4	28.2	14.6	7.0	2.31	144.4	6.94
120	Limestone	Stone	4.7	8.5	33.6	13.3	5.0	2.66	165.3	0.43
121	Limestone	Lawrence	11.8	3.4	34.6	10.5	4.0	2.63	164.4	0.33
122	Dolomite	Lawrence	16.8	2.4	37.6	15.8	11.0	1.91	119.4	16.72
123	Creek Gravel	Lawrence	...	...	36.0	...	...	...	....	....
124	Limestone	Dade	6.8	5.8	31.0	7.4	5.0	2.64	162.9	0.49
125	Flint Boulders	Dade	8.4	4.8	12.8	12.3	9.0	2.48	155.0	2.79
126	Limestone	Greene	7.7	5.2	46.2	6.8	5.0	2.66	166.3	1.66
127	Dolomite	Greene	6.7	5.9	12.4	15.5	12.5	2.26	141.3	6.22
128	Creek Gravel	Greene	...	...	25.6	...	...	...	....	....
129	Dolomite	Webster	7.8	5.1	6.04	0.0	6.0	2.50	156.3	3.04
130	Dolomite	Webster	10.1	3.9	74.6	14.4	17.0	2.33	145.6	4.37
131	Dolomite	Laclede	7.9	5.1	51.2	15.5	13.0	2.73	170.6	0.73
132	Creek Gravel	Laclede	...	...	56.0	...	...	...	....	....
133	Dolomite	Polk	7.2	5.6	33.4	11.3	7.0	2.54	158.7	4.86
134	Dolomite	Polk	8.4	4.8	69.2	4.5	10.0	2.35	146.9	8.37
135	Limestone	St. Clair	8.4	4.8	36.2	12.7	6.0	2.65	165.6	2.82
136	River Gravel	St. Clair	...	...	50.6	...	...	...	....	....
137	Limestone	Osage Co	8.9	4.5	28.4	6.7	6.0	2.55	159.4	5.88
138	Creek Gravel	Osage Co	...	...	80.2	...	...	...	....	....
139	Dolomite	Osage Co	10.1	3.9	43.6	9.0	8.5	2.65	165.5	3.81
140	Dolomite	Gasconade	5.9	6.8	58.4	12.7	9.0	2.50	157.3	7.84
142	Limestone	Franklin	4.8	8.3	19.0	12.6	15.5	2.53	157.8	6.41
143	Limestone	Franklin	9.1	4.4	23.6	12.1	10.0	2.66	166.4	4.66
144	Bank Gravel	Franklin	...	...	41.0	...	...	...	....	....
145	Limestone	Gasconade	6.3	6.3	71.2	15.2	13.5	2.58	161.0	8.00
146	Creek Gravel	Gasconade	...	...	36.2	...	...	...	....	....
147	Hill Gravel	Maries	...	...	26.4	...	...	...	....	....
148	Creek Gravel	Maries	...	...	5.8	...	...	...	....	....
149	Limestone	Maries	52.3	0.8	36.0	5.3	6.5	2.62	163.7	6.97
150	Limestone	Dent	4.2	9.5	22.2	11.5	12.0	2.62	163.7	2.43
151	Hill Gravel	Dent	...	...	31.2	...	...	...	....	....
152	Creek Gravel	Dent	...	...	75.8	...	...	...	....	....
154	Limestone	Crawford	11.0	3.6	25.6	1.3	8.0	2.67	167.0	3.34
155	Hill Gravel	Crawford	...	...	12.2	...	...	...	....	....
156	Creek Gravel	Crawford	...	...	44.6	...	...	...	....	....
158	Limestone	Phelps	6.0	6.6	15.8	12.7	12.5	2.72	170.0	4.10

TABULATION OF RESULTS.

NUMBER.	NAME.	COUNTY.	Percent of Wear	French coeff. of Wear.	Cementing Value.	Hardness	Toughness	Specific Gravity	Weight per cu. ft. —solid form	Water absorbed in lbs. per cu. ft.
159	Sandstone	Phelps	41.8	0.9	16.0	6.3	3.0	2.32	145.0	10.30
160	Creek Gravel	Phelps	...	...	23.8	...	...	...	....	....
161	Limestone	Phelps	5.7	7.0	59.6	12.5	10.0	2.60	162.0	6.48
162	Limestone	Texas	5.1	7.8	30.4	12.7	10.0	2.64	165.0	2.64
163	Creek Gravel	Texas	...	...	8.6	...	...	...	....	....
164	Hill Gravel	Texas	...	...	14.4	...	...	...	....	....
165	Creek Gravel	Howell	...	...	37.2	...	...	...	....	....
166	Sandstone	Howell	47.6	0.8	4.4	4.3	2.0	2.50	157.7	3.21
167	Rhyolite	Shannon	4.0	10.0	50.0	18.6	23.5	2.71	168.5	0.10
168	Limestone	Shannon	6.5	6.2	40.0	10.3	11.5	2.73	170.6	1.02
169	Creek Gravel	Shannon	...	...	16.8	...	...	...	....	....
170	Granite	Carter	2.7	14.8	34.2	19.3	14.0	2.68	167.5	2.18
171	Limestone	Carter	5.4	7.4	19.8	9.7	11.0	2.79	174.5	1.57
172	Creek Gravel	Carter	...	...	17.8	...	...	...	....	....
173	Sandstone	Carter	56.4	0.7	8.6	5.0	4.5	2.32	145.0	5.80
174	Limestone	Reynolds	8.8	4.5	37.6	9.8	12.5	2.82	176.4	1.59
175	Creek Gravel	Reynolds	...	...	26.6	...	...	...	....	....
176	Sandstone	Reynolds	40.2	1.0	5.2	6.1	3.0	2.37	147.0	4.47
177	Granite	Wayne	1.8	22.1	69.4	17.9	28.0	2.72	169.9	0.80
178	Limestone	Wayne	7.6	5.3	26.0	10.4	12.0	2.86	178.7	0.45
179	Creek Gravel	Wayne	...	...	15.6	...	...	...	....	....
180	Sandstone	Wayne	20.4	1.9	4.6	4.6	3.0	2.59	160.5	5.50
181	Limestone	Butler	6.4	6.4	42.0	9.9	8.0	2.87	179.4	1.43
182	Creek Gravel	Butler	...	...	9.0	...	...	...	....	....
183	Limestone	Ripley	2.3	17.3	40.0	16.1	14.0	2.85	178.3	0.89
184	Chert	Ripley	5.6	7.1	52.6	11.6	9.0	2.50	157.3	5.19
185	Creek Gravel	Ripley	...	...	20.2	...	...	...	....	....
186	Quartzite	Ripley	3.8	10.5	29.8	15.7	16.5	2.99	186.5	1.49
187	Hill Gravel	Scott	...	...	38.0	...	...	...	....	....
188	Limestone	Scott	4.5	8.9	60.2	13.3	5.0	2.69	168.1	1.84
189	Chert	Scott	6.4	6.3	42.4	9.9	10.0	2.40	150.0	0.30
190	Limestone	Cape Girardeau	4.4	9.1	20.6	13.8	14.5	2.72	170.0	0.22

191	Sandstone	Cape Girardeau	5.3	7.5	40.6	12.5	12.5	2.36	147.5	3.54
192	Limestone	Cape Girardeau	7.0	5.7	39.0	10.7	12.0	2.69	167.0	1.01
193	Creek Gravel	Cape Girardeau	...	...	32.2	...	...	...	....	....
194	Limestone	Bollinger	5.7	7.0	46.6	9.1	6.0	2.56	160.0	4.70
195	Creek Gravel	Bollinger	...	...	14.0	...	...	...	....	....
196	Limestone	Madison	4.3	9.3	56.0	16.2	8.0	2.74	171.3	2.05
197	Ryolite	Madison	1.8	22.1	49.2	18.1	26.0	2.62	163.8	0.26
198	Kaolin	Madison	15.1	2.6	78.4	9.2	6.5	2.20	137.5	6.30
199	Granite	Madison	2.5	16.0	20.8	16.8	19.0	2.61	162.8	1.62
200	Creek Gravel	Madison	...	...	12.8	...	...	...	....	....
201	Sandstone	Madison	23.0	1.7	12.4	4.7	4.0	2.44	152.5	4.46
202	"Chats"	Madison	...	...	9.6	...	...	...	....	....
203	Granite	St. Francois	2.5	16.0	39.0	19.0	25.5	2.67	167.0	0.84
204	Granite	St. Francois	1.9	21.0	23.0	18.9	17.0	2.68	167.5	0.20
205	Granite	St. Francois	4.2	9.5	21.8	12.8	16.5	2.71	169.4	0.51
206	Creek Gravel	St. Francois	...	...	11.0	...	...	...	....	....
207	Chats	St. Francois	...	...	20.8	...	...	...	....	....
208	Limestone	St. Francois	4.5	8.9	21.6	10.1	13.5	2.87	175.6	1.53
209	Limestone	St. Francois	4.7	8.5	30.6	13.6	15.0	2.65	165.6	0.83
210	Sandstone	St. Francois	28.1	1.4	4.6	5.1	4.5	2.39	149.4	3.73
211	Porphyry	St. Francois	2.7	14.8	89.0	19.7	15.0	2.64	164.5	0.59
212	Granite	Iron	3.5	10.4	40.8	14.4	19.0	2.63	164.4	0.32
213	Red Hematite	Iron	5.6	7.1	36.2	17.2	13.0	3.89	243.0	1.22
214	Limestone	Iron	5.2	7.7	51.0	12.8	13.5	2.76	172.3	3.45
215	Porphyry	Iron	3.5	11.4	78.8	15.3	20.5	2.67	166.9	0.03
216	Creek Gravel	Iron	...	...	22.8	...	...	...	....	....
217	Limestone	Washington	7.4	5.4	40.4	13.6	10.0	2.79	174.4	0.52
218	Creek Gravel	Washington	...	...	9.0	...	...	...	....	....
219	Limestone	Jefferson	4.9	8.2	15.6	6.8	5.0	2.44	152.5	11.43
220	Creek Gravel	Jefferson	...	...	22.8	...	...	...	....	....
221	Limestone	St. Genevieve	3.8	10.5	28.6	9.9	6.0	2.69	168.1	1.50
222	Creek Gravel	St. Genevieve	...	...	56.6	...	...	...	....	....
224	Limestone	Perry	3.5	11.4	32.0	15.1	8.0	2.75	161.9	1.64
225	Creek Gravel	Perry	...	...	23.2	...	...	...	....	....
226	Creek Gravel	Montgomery	...	...	15.6	...	...	...	....	....
227	Limestone	Montgomery	5.3	7.5	117.2	4.5	5.0	2.66	166.3	1.33
228	Chert	Pulaski	4.4	9.1	45.6	10.7	12.5	2.65	156.7	1.25
229	Limestone	Pulaski	8.6	4.7	35.0	13.2	9.5	2.62	163.8	5.25
230	Limestone	St. Genevieve	6.3	6.3	32.8	13.7	12.5	2.69	168.2	0.50
231	Silica	St. Louis	...	...	36.6	...	...	...	....	....
232	Creek Gravel	St. Louis	...	...	17.6	...	...	...	....	....
233	Creek Gravel	Stoddard	...	...	30.0	...	...	...	....	....
234	Flint or Chert	Boone	5.9	6.8	17.4	...	...	...	....	....
238	Creek Gravel	Boone	2.6	15.4	52.2	...	...	...	....	....
239	Flint, "Chats"	Jasper	...	...	32.8	...	...	...	....	....
240	Rotten Granite	Iron	...	...	46.9	...	...	...	....	....
242	Limestone	Audrain	4.9	8.2	112.0	...	...	2.71	169.4	0.67

CONCLUSION.

From a study of these samples of road material and the results of the tests made on them, the following conclusions have been drawn.

Limestone is the most abundant and most widely distributed road material in the state; but unfortunately the tests show that only about 38% of the samples of this rock are classed as medium in wearing qualities, and about 62% are classed as low in wearing qualities, or too soft for roads, except for very light traffic. These soft limestones make a dusty road in dry weather and a muddy road in the wet weather. The dust produced by the wear of traffic is blown away by the winds or washed away by the heavy rains, so the stone is not protected by the dust from further wear. The automobile traffic also removes this fine dust from between the stones and the wind blows it away and causes the road to ravel. These conditions can be improved by the use of oil and the wear will be lessened to some extent. Nearly all of the samples of limestone show good cementing qualities and some are excellent in this respect; this suggests their use for a foundation for permanent roads where they are abundant and cheap; a harder and tougher material, such as creek gravel, granite or rhyolite, being used for the wearing surface. A finely crushed limestone of good cementing value might also be used as a binder for creek gravel which is often deficient in binding quality. There are also some localities where, for economic reasons, the foundation of a road might be constructed of a soft or brittle limestone and the wearing surface be constructed of a harder and tougher limestone with better wearing qualities, which was not so plentiful or had to be transported a longer distance.

The gravels in this state are derived from three sources, rivers and streams, glacial deposits, and residual deposits. From whatever source it may be derived, it is usually the hardest material to be found in the locality where it occurs as the softer materials have been disintegrated or worn away by the action of water and ice; it is therefore usually a good wearing material for road surfaces.

The gravel found in rivers and streams, commonly called creek gravel, is usually smoother and more nearly round than that in either the glacial or residual deposits, and contains very little or no clay. The chief constituent of the creek gravel in central and south Missouri is chert or flint which does not have good cementing qualities. On account of the low cementing value of these hard chert pebbles and the rounded shapes of the stones most creek gravel does not bond readily when placed on the road; but remains loose until a sufficient amount of loam, clay, or other foreign matter has been carried onto the road to form a binder. The addition of clay will make a well bonded road, but this will cause the gravel to pick up in very wet weather and the road surface will be broken up by freezing and thawing as the clay will hold a large amount of water. It is thought therefore that the addition of a finely crushed limestone, or other stone of good cementing value, will greatly improve most of the creek gravels and form a well bonded and durable wearing surface.

The glacial gravels in Missouri are usually imbedded in clay and sand and the percentage of clay and sand is usually so great as to make it undesirable for road purposes. When the clay exceeds 30% the gravel is considered undesirable. A part of the creek gravel in the streams north of the Missouri River is of glacial origin, having been washed down into the streams by the erosion of the gravel beds.

The gravel which comes from the residual deposits are found throughout the Ozark region on the ridges and hills. This consists of angular fragments of chert or flint mixed with clay and it is known as hard-pan gravel or hill gravel. If the percentage of clay is not too great (less than 25 or 30 per cent) this material forms a hard and compact road surface. It is however easily eroded by water and requires quick and thorough drainage. On account of the clay holding so much water the road surface is liable to be broken up by freezing and thawing.

The best rocks in the state for road purposes are the granites, rhyolite, and porphyry found in St. Francois, Iron, Madison, Wayne, Carter, and Shannon counties. These rocks all have good cementing qualities and they are hard and tough enough to resist the wear of heavy traffic.

These tests are not to be considered as complete for all of the road materials of the state as some counties were not visited at all by the collectors and not all parts of the counties visited were examined; so there are many localities and many quarries in the state that are not represented in this bulletin. If any of the Highway Engineers, owners of quarries, or other citizens in the state interested in good roads, will send in samples of stone or gravel they will be tested by the Engineering Experiment Station and a report made on the results.

INSTRUCTIONS FOR SAMPLING AND SHIPPING.

In taking samples of stone from a quarry or ledge care should be taken to get a sound, fresh, unweathered sample representative of the interior stone.

When all material in a quarry is of practically the same variety, texture, etc., one sample will suffice. If however there are different varieties in the same quarry separate samples of each variety should be taken and a report made on the position and extent of each. The stone should not be finely crushed.

In order to have sufficient stone to make the tests, samples should weigh at least 25 lbs. and one piece of each sample should measure not less than 3x4x5 inches in order that a core may be drilled therefrom.

The thickness of the ledge or the face of the quarry should be reported, also the extent of the country in which such stone is found. Report the name of the quarry, or the land owner's name, and the exact location of the quarry with reference to the nearest town or Post Office.

Samples of gravel should be taken with the sand or clay just as it occurs in the stream or gravel bank.

Ship in strong grain bags or tight boxes and mark each sample so it can be identified with the report, which should be sent by mail. To insure prompt and sure delivery ship by prepaid express to the Civil Engineering Laboratory, care of the University, Columbia, Mo.